FIGHTING FOES TOO SMALL TO SEE

JOSEPH McFARLAND

Anthony van Leeuwenhoek. The discoverer of the bacteria.

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BY

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PREFACE.

The text that follows had its beginning in a series of four lectures, delivered at the Wagner Free Institute of Science of Philadelphia, under the fund of the Richard B. Westbrook Free Lectureship, on the evenings of January 19th and 26th, and February 2d and 9th, 1921.

In the letter of invitation and the conversations that followed it, the writer was informed that the lectures were to be upon "some phase of Microbiology," and were to be popular, yet "scientific accuracy was not to be sacrificed for popularity."

It was with some doubt as to the outcome, that the course was undertaken, as "Microbiology" seemed to be a subject having so technical a sound that it might tend to frighten people away instead of inviting them to attend.

However, a large audience came to the first lecture, and became sufficiently interested to continue to attend throughout the remainder of the course.

The manuscript notes of those lectures have been transformed and amplified into the present little volume.

J. McF.

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INTRODUCTION.

It may seem odd to the casual reader, who usually passes it by, that an author expects the introduction to his book to be read; that he writes it for that express purpose, and expends thought upon it. That it may sometimes be prosy there can be no doubt, as any one that has read the one or two introductions with which each of the Waverley Novels begins, or has waded through the long introduction to Prescott's "Conquest of Mexico," knows. Yet in each case, the writer was endeavoring to prepare the reader for what was to follow by placing before him the sources of the narrative contained in the subsequent pages and thus make the story real, or to work up an atmosphere suitable to its action.

This book needs an introduction to make the reader understand that it was written for him, and for him to read.

A publisher to whom the manuscript was shown, after looking over various pages, returned it with these words: "This is a technical book, and ordinary people will not understand it." Another, having done the same thing, returned it with just the reverse opinion: "This is not a technical work, it is popular; we only publish technical medical works."

A medical friend remarked: "You are placing before the general public, that which it is impossible for them to understand. They know nothing of these things." A lay friend, on the other hand, expressed his opinion that, "it contained just what he had long wanted to know, and did not know how to find." He also expressed the opinion that, "anybody could understand anything in it." With that opinion I am in full accord.

Doctors are prone to be full of conceit. Many of them seem to feel that they have some monopoly of intellect and information, and that such matters as form the substance of this book are their exclusive prerogative and beyond the capacity of all others.

Let no doctor deceive you. You are just as intelligent as he, probably just as well educated, and just as capable of understanding. Many of the most important facts to be dealt with were found out by others than doctors, and doctors were sometimes the last to understand and profit by their significance and far-reaching importance. It was a doctor that said the last word in support of the foolish doctrine of the Spontaneous Generation of Life; it was the doctors of his day that longest opposed Jenner when he began his prevention of smallpox by Vaccination; it was the doctors of his day who most persistently opposed the doctrine of the

Germ Theory of Disease, when Pasteur began to explain it.

Let no reader be discouraged because this book deals with what may be unfamiliar to him; it is written to make him familiar with those very things. Let him not fear that he may not be able to understand the long words he may see upon its pages; those words are really simple, and not so important as the ideas they are employed to express. Anyone can understand the ideas, and they constitute the message the book is intended to convey.

The unknown when unexplained frequently strikes terror to the human soul.

To the ancients, the unexplored ocean, beyond those horizons they were accustomed to see, was filled with chimerical monsters, and verged upon a terrible abyss into which too venturesome ships must fall: we have learned that the earth is a sphere, the seas have been explored, and the abyss disappeared, and the chimeras become extinct. Though occasional accidents befall, they are recognized to be the results of natural causes, and no mariner now fears to navigate the globe.

To many primitive peoples the mountains were the abode of the gods, or were haunted by evil spirits and were taboo; civilized man, having ascended nearly all of their highest ranges, has found them to

be but irregularities of the earth's surface. Upon them accidents occasionally happen, but always from natural causes, and no one hesitates to climb.

The appearance of a comet, or the occurrence of an eclipse was a presage of the coming end of the world: but with the discovery of the movements of the celestial bodies, both have become but natural events simple of explanation, to be predicted and watched for as aids in the demonstration of new and perhaps important facts of science.

To the Orientals and to medieval man epidemics of disease mysteriously appeared from nowhere and disappeared for no reason. To explain them the stars were called upon; to stay them the gods were implored, and sacrifices, prayers and fastings ordained. We now know that they are but the result of the dissemination of minute living entities carried by perfectly natural means from country to country and from man to man, attacking and destroying those weaker than themselves. They have their parallels in the misfortunes of agriculture such as the occasional devastating appearances of locusts, of army worms, of cut-worms, of cotton boll-weevils, of seventeen year locusts, of gypsy moths, and many other well-known enemies of the forests and fields.

So soon as the life history of one of these insect enemies becomes known, the terror it inspired dis-

appears, and though it may not always be possible immediately to devise the appropriate means of successfully combatting it, men set about further investigation with the practical end of extermination of the enemy in mind, and the salvation of their crops in view.

So it is with the infectious and epidemic diseases: when the causes are not known, and the means of transmission uncertain, we are more or less helpless to prevent them, as is shown by the uninterrupted spread of influenza during its last visitation. So soon as the cause is determined, prevention quickly follows, as a rule, as is shown by the successful eradication of that most devastating disease, the plague, from our country, without any serious loss of life or alarm of the people. We are not interested in the treatment of disease; that is the office of the doctors. We are interested in its prevention; that is everybody's work.

Following knowledge of the cause and prevention of the infectious and epidemic diseases, there have gradually grown up and assumed importance, groups of officials, investigators, and workmen, collectively known as the "Sanitary Authorities." These men are at work all the time in all countries, and it is chiefly due to their labors that great epidemics are now prevented. When their work is

successful, nothing amiss happens, and the average citizen is unconscious of the fact that his health, and perhaps his life, have been in jeopardy. When they fail, illness and death settle upon the community. Quick to seize upon every new fact in science, and calling to their assistance the best brains among doctors and engineers, they have devised systems of collective and co-operative action that promise far-reaching results. Some of the measures now in practice were devised by doctors, some by laymen; it may now be impossible to say who first suggested them or insisted upon them.

But it is sometimes a difficult task to secure concerted action in sanitation even among the doctors; many are too strongly individualized to surrender what they boldly declare to be "their freedom of action." In successful sanitation there can be no freedom of individual action.

The evasion of any regulation, the purpose of which is the promotion of the public welfare is criminal, whether the offender be a doctor or another. It is individual evasions, sometimes from ignorance, sometimes from avarice that interrupt the hoped for success.

In India where some 20,000 persons are annually fatally bitten by venomous snakes, the government once offered a bounty for cobras, in order to effect

their extermination, but without accomplishing the end. Greedy, cunning and lazy natives bred cobras instead of killing the wild snakes, and collected the bounties. No good came of the plan. There were as many snakes at large as before.

It is said that in some places where the government offered a bounty on rats to prevent plague, the same system was attempted. There are always some people out of sympathy with any law, usually because they do not understand it or why it was enacted, or because it restricts their liberty, or because it interferes with their profit. Such people may evade it, and through their lack of co-operation its intended wholesome effects may be undone. This is true, in regard to laws concerning sanitation. There are said to be doctors who will, for money, pretend to vaccinate a child, but knowingly and intentionally perform some useless scarification from which no benefit can be derived, thus giving a false impression of conforming with the law. Fortunately this usually does no serious harm, as the majority of children are efficiently vaccinated. But, if in imagination, the circumstance be multiplied many times, and the number of unprotected children thus becomes great, disaster in the form of an epidemic associated with great loss of life, may, at any time ensue.

If any one believes the legal enactments under which the sanitary officials operate, to be tyrannous, antiquated, ineffective, or otherwise objectionable, it is within his rights, and it may even be his duty to say so, and to endeavor to have them modified. But before doing so, or failing in his endeavors to do so, he is, as a good citizen, bound to observe them.

It is the duty of every good citizen to obey the law, because it is the law. Willingness to evade the law because out of sympathy with it can only lead to disorder. Avowed willingness to accept the penalty for evading the law, is equally bad. Suppose that every vindictive man, because out of sympathy with the law against homicide, killed his man, and accepted his punishment; or that every avaricious man, out of sympathy with the law protecting private property, took his neighbor's goods, and accepted the punishment, where would we be? There could be no law and no order, and we would sink into the barbarous condition of early Bolshevist Russia. Good citizens obey the law because it is the law, the more in our country because it is their own law—that made by their legal representatives. Bad citizens must be made to obey the law by the certain enforcement of sufficiently severe punishments. The present aftermath of the war shows a dismal decline in public morals, in which one of the

most distressing is apparent loss of that moral sense that was once so strong, in guiding the affairs of our country. Murder, theft and arson are common crimes, yet the criminals are not caught and brought to judgment, or if they are, justice fails because of judicial abuse in the admission of trifling technicalities to cloud the issue, the suppression of evidence for technical reasons, or because of the influence of political friends of the criminal upon the court.

A great epidemic may destroy as many lives, and cost as much treasure as a great war. It is not a matter for individual judgment. In its prevention as well as in its extinction all must co-operate.

The war gave us a new word—"Preparedness." Many have insisted that preparedness implies a state likely to be dangerous through the temptation to aggression. In the preparedness against epidemic disease the only aggression is against inhuman foes, from whom we can want nothing, and can take nothing, but by whom we may be invaded, devastated and depopulated. We must fight these foes too small to see!

Is it not worth while to be forewarned about them by learning about their life and habits? Is it not worth while to be prepared for them, lest they come? Is it not important to co-operate against them? Is it not the duty of every citizen to realize his personal

responsibility in the contest that may at any time threaten? What was it the old Roman said?

Salus populi suprema est lex.

THE INVISIBLE FOES.

The greatest enemies of mankind are not those he essays to combat with shot and shell, but tiny creatures that he cannot see—microbes.

Though most people have heard about them, their knowledge is apt to be very superficial, which is quite pardonable, as special knowledge can only be obtained through the employment of apparatus of a kind possessed by very few.

It goes without saying that if an object cannot be seen without a microscope, it could neither have been seen nor known before microscopes were invented. It would be very interesting in this connection to know who was the inventor of this now indispensable instrument, but unfortunately history is uncertain about it, and as the matter is investigated, it becomes complicated. For example, what is a microscope?

Simple lenses were, of course, invented and used before they were combined in a series to constitute the modern compound microscope. But we are ignorant of their invention, and do not know in what country or by what people they were first used. Some suppose that they were invented very early. Layard found a convex lens of rock crystal in the

ruins of the palace of Nimrod. In his well-known novel, "Quo Vadis," Sienkiewicz pictures the Roman emperor Nero as peeping through a large polished

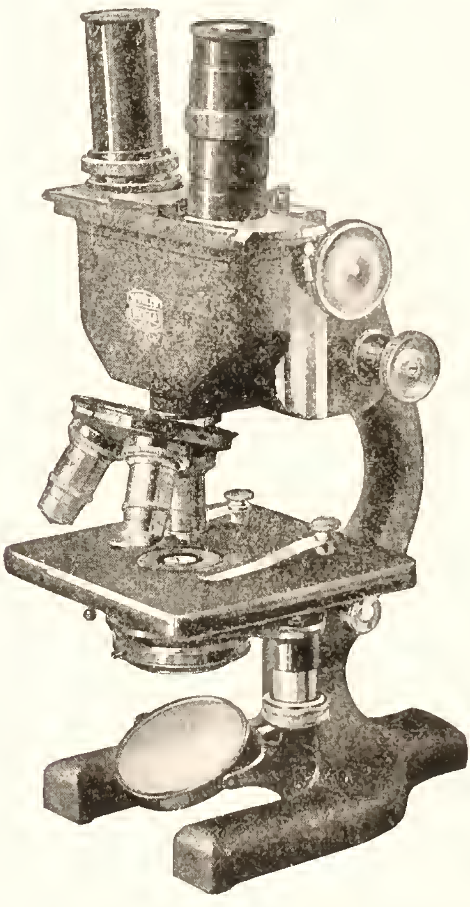


Fig. 1.—Modern American research microscope.
(The Spencer Lens Company.)

emerald to assist him in overcoming the difficulty of nearsightedness. It may be that such use of lenses was known in his time, but the writers of that day say nothing about it, and no mention of

assisting vision by the aid of lenses or polished jewels appears in literature until centuries later. Seneca, Nero's tutor, however, speaks of the use of hollow spheres of glass filled with water, as magnifiers, and it has been very properly pointed out that the perfect jewel-cutting and other fine work

Fig. 2.—An ancient Assyrian 'lens' (?).

From Carpenter, "The Microscope and Its Revelations," J. and A. Churchill, publishers, London, England.

of the ancients could hardly have been performed without the aid of some artificial assistance to vision.

We are doubtful whether lenses were used to correct defective vision before the thirteenth century.

Professor Govi, who has devoted himself to the history of the microscope, has reached the conclusion that the compound instrument was invented by Galileo, who lived between 1564 and 1642. If Govi be

correct, its invention must therefore have been made somewhere about the beginning of the seventeenth century. Others, supposed to be competent to judge, think the invention is to be attributed to

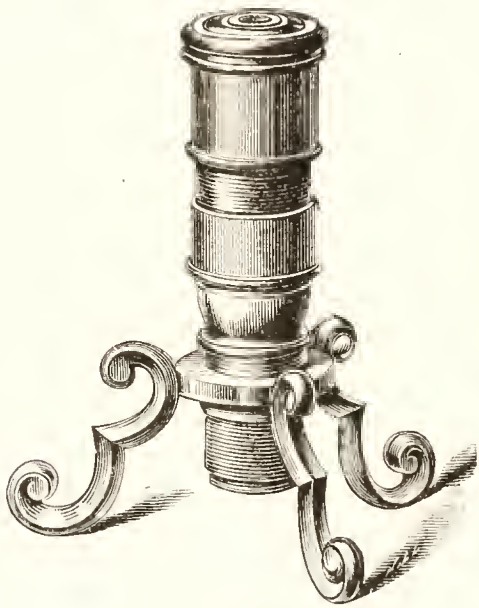


Fig. 3.—Galileo's microscope.

From Carpenter, "The Microscope and Its Revelations," J. and A. Churchill, publishers, London, England.

Hans and Zacharias Janssen, spectacle makers of Middleburg, Holland, between 1590 and 1609.

Descartes in his "Dioptrique", 1637, describes microscopes wherein a concave mirror, with its concavity towards the object, is used in conjunction with a lens, for illuminating an object which is mounted on a point fixing it at the focus of the mirror.

Readers interested in the subject will find it well discussed in "The Microscope and its Revelations" by William B. Carpenter.

These early instruments were, however, so de-

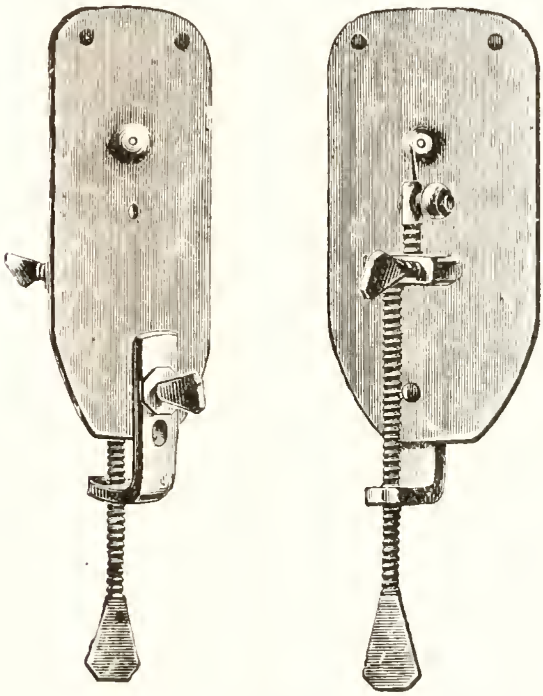


Fig. 4.—Leeuwenhoek's microscope (1673).
From Carpenter, "The Microscope and Its Revelations,"
J. and A. Churchill, publishers, London, England.

fective that very little of real value could be gained by their use, and they must have been interesting toys rather than working apparatuses.

The same did not apply to simple lenses. In their manufacture great improvement was made, and in 1683, Anthony van Leeuwenhoek, a grinder of

lenses, of Delft, Holland, made for himself one with such excellent powers of definition that, with it, he was able to make many interesting observations, that he reported to the Royal Society of London, and among which was the discovery of the minute organisms that are to be considered in the following pages—the bacteria.

But nearly two centuries more had to elapse before this discovery and further improvements in the construction of the microscope began to bear fruit in the practical application of the knowledge of the micro-organisms to the important problems of medicine and public health.

And it was not until then that it came to be recognized by scientific men that the discovery of Leeuwenhoek was comparable with that of Christopher Columbus: the one discovered a new world in the geographical sense, the other a new world in the biological sense.

To all of the tiny creatures he discovered, Leeuwenhoek applied the term "animalculæ"—little animals—because they swam about in the fluids in which he observed them, very much as animals might be expected to do.

They seemed to be endless in form and variety, but we know that there were bacteria among them because of the drawings he made.

But animalculæ they were called by their discoverer, and such they remained for a long time, and I often wonder whether the students of the present day with knowledge that has been added to by a succession of later inventions such as the ultra-microscope and the dark field illuminator, and supplemented by the various contributions from the science of Biology, who talk glibly about Bacteria as the most minute of plants, and know tables for their identification and classification, have any idea of the long years of study and observation required to reach the present state of knowledge.

To most persons these tiny creatures are known as "Microbes," and the word, introduced by the French, is an excellent one that means only *little live things*, and does not commit one to any theory in regard to them.

They are, however, divisible, just as larger living beings are, into plants and animals, and among the invisible enemies about which we are concerned in the following pages, both of these groups are represented.

In many cases there is great difficulty in definitely deciding to which of the groups some particular infinitesimal enemy belongs, but that is really a very unimportant matter, and in the considerations that are to follow we shall not bother about the

animal or plant nature of the particular micro-organisms concerned.

But in passing it may be well to pause a moment, to explain to those unfamiliar with these matters how a scientist decides in doubtful cases what is an animal and what a plant.

To most people this seems easy enough. They have in mind the animals—mice, dogs, horses, elephants—that they know, and the plants—roses, potatoes, ferns and chestnut trees—that are so unlike them. But what if one has to deal with a new creature, not at all like anything previously seen—say something that looks like a cucumber, but swims about in the water in which it is found? In such cases it is necessary to have some definite and scientific means of deciding, and that now universally accepted may strike you as very peculiar. The decision as to the animal or plant nature of the new creature depends upon its means of living.

If it be able to draw upon the oxygen and carbon dioxide of the atmosphere and the water of the soil, and combine these into the higher compounds of which its own substance consists, it is a plant. Here is an example: a potato plant grows in the ground; the rain brings it the necessary water, and dissolves certain salts in the soil—ammonia, potassium, calcium, magnesium, sulphur, phosphorus and

iron—all of which are necessary in minute amounts, so that the plant may utilize them; from the surrounding atmosphere it absorbs oxygen, carbon dioxide and perhaps nitrogen. With these comparatively simple substances, in the presence of sunlight, it is able to build up more and more complex compounds thus: out of the carbon dioxide (CO_2) and water (H_2O), are formed formic aldehyde

$$CO_2+H_2O=CH_2O \text{ (formic aldehyde)}+O_2$$

By a continuation of the same kind of process the formic aldehyde is advanced to mono-saccharid

$$6CH_2O=C_6H_{12}O_6$$

By still further additions and rearrangements further advance to starch and cellulose is made

$$nC_6H_{12}O_6-nH_2O=(C_6H_{10}O_5)n=\text{starch and cellulose.}$$

This chemical interaction is called *photosynthesis*, and can only take place in the presence of sunshine, and after a peculiar green substance, *chlorophyl*, largely peculiar to plant life has first been formed.

No animal can do this, but can only live upon complex compounds that have been previously prepared by plants.

Such a means of separating animals and plants may seem to be a difficult and cumbersome one, but it works well in the hands of those knowing how to

apply it, and only fails in a few cases, in which what are undoubtedly animals, from all the other criteria employed for differentiation, are found to contain chlorophyl, or in which what are undoubtedly plants contain no chlorophyl and so must live as the animals do.

In this circumstance we find one of the great truths of biology. *There are no rules without exceptions.* In it we also find one of the difficulties in the way of accurately classifying the micro-organisms. Many of them are exceptions to the rules. and concerning a number we are in doubt as to their animal or plant nature.

To overcome the difficulty Haekel, as late as 1878, recommended that micro-organisms of this doubtful character be placed in a separate group of living things, not definitely either plants or animals, for which he suggested the name "Protista."

Fortunately the whole discussion is of academic interest only, has no practical value, and may be dismissed. We shall treat the micro-organisms for the most part without reference to their animal or plant nature.

But there were other difficulties that beset the path of the pioneer investigators. The micro-organisms are not only extremely small, they are also extremely transparent. They were therefore ex-

tremely difficult to see until chemistry had furnished the investigators with aniline colors by which they could be stained. Nearly all important knowledge of micro-organisms has been gained through the study of stained preparations.

WHAT IS THE ORIGIN OF THE MICRO-ORGANISMS?

For many years after their discovery more interest was taken in wondering where the micro-organisms came from than in inquiring what they were or what they did. That they were alive and were "animalculæ" was sufficient, but where they came from seemed to be very mysterious. Nearly all of the investigators of a century ago seemed to be of the opinion that if objects are small and of simple structure, it must be more easy for them to come into existence than if they are large and complex. I am not sure that the same thought does not occur to us today, but we have learned that it is not true; therefore we express wonder that our forefathers were almost in accord in believing that when proper conditions were provided, life would appear spontaneously.

THE SPONTANEOUS GENERATION OF LIFE.

For centuries this philosophical doctrine led earnest scientific men into extravagances of thought and speculation, from which it has been so difficult to recover that it was not until about 1915 that the last vestige of it seems to have become extinguished in the smoke of the publications of Dr. H. Carlton Bastian.

But among people ignorant of science it still lurks, and will probably continue to do so for many years. You must not be surprised, therefore, to find intelligent and otherwise well-informed people who will assure you that vermin arise from uncleanliness, the dirt engendering the lice, bedbugs or roaches, or when, in the country, you are told that the horse-hair seen in the watering trough will eventually turn into a long and slender worm. A very well educated gentleman once explained to me that the slime and ooze of the meadow pools was the source of the frogs that lived in it.

VIEWS OF THE ANCIENT GREEK PHILOSOPHERS.

If we go far enough back in history, we find that almost all peoples believed living things to have been created by their gods. The Greeks seem to have been the first to outlive this idea, and before

the beginning of the Christian era, their philosophers began to teach that living things came into existence *spontaneously.* Such "coming into existence" was not conceived, like creation to have taken place long ago, at the beginning of time, but to be taking place all the time, whenever and wherever conditions were favorable.

Anaximander taught that animals were formed through the stimulating effects of moisture; another, Empedocles, 490-430 B. C., taught that all living things arose "spontaneously,"but in a peculiar and interesting manner. William Walton in the XI Edition of the Encyclopedia Britannica, summarizes what he says, as follows:

Empedocles recognized four primal divinities, of which are made all structures in the world—fire, air, water and earth. These four elements are eternally brought into union, and eternally parted from one another by two divine beings or powers, love and hatred—an attractive and a repulsive force which the ordinary eye cannot see working amongst men, but which really pervade the whole world. According to the different proportions in which these indestructable and unchangeable matters are combined with each other, is the difference of the organic structure produced—*e.g.*, flesh and blood are made of equal (in weight, but not in volume) parts of all four elements whereas bones are one-half fire, one-fourth earth, and one-fourth water. It is in the aggregation and segregation of elements thus arising, that Empedocles, like the anatomists, finds the real process which corresponds to what is properly called growth, increase and decrease. Nothing new comes or can

come into being, the only change that can occur is the change in the juxtaposition of element with element.

Empedocles apparently regards love and discord as alternately holding empire over things—neither, however, being quite absent. At the best and original state, he seems to have conceived a period when love was predominant, and all the elements formed one great sphere or globe. Since that period discord had gained more sway; and the actual world was full of contrasts and oppositions due to the combined action of both principles. His theory attempted to explain the separation of the elements, the formation of the sea, of the sun and moon and atmosphere.

But the most interesting and most matured part of his views dealt with the first origin of plants and animals, and with the physiology of man.

As the elements (his deities) entered into combinations, there appeared quaint results—heads without necks, arms without shoulders. Then as these fragmentary structures met, there were seen horned heads on human bodies, bodies of oxen with men's heads, and figures of double sex. But most of these products of natural forces disappeared as suddenly as they arose; only in those rare cases when the several parts were found adapted to each other, and casual member fitted into casual member, did the complex structures thus formed last. Thus from spontaneous aggregations of casual aggregates, which suited each other as if this had been intended, did the organic universe spring. Soon various influences reduced the creatures of double sex to a male and a female, and the world was replenished with organic life. It is impossible not to see in this theory a crude anticipation of the "survival of the fittest" theory of modern evolutionists.

The greatest of the Greek scientists, Aristotle, who seems to have known more about the living things

than all of his contemporaries put together, hesitated to commit himself to so general a view, yet, knowing no more about the matter than others, found himself under the necessity of admitting the probability that "sometimes animals were formed from putrefying soil, sometimes in plants, and sometimes in the fluids of other animals."

VIEWS OF THE ROMAN PHILOSOPHERS.

In the fourth book of the Georgics, Virgil gives the following directions for the spontaneous generation of bees:

First, a space of ground of small dimensions, and narrowed for this purpose is chosen; this they cover in with the tiling of a narrow roof and with confining walls, and add four openings with a slanting light turned towards the four points of the compass.

Then a bullock, just arching his horns upon his forehead, of two years old, is sought out; whilst he struggles fiercely, they close up both his nostrils and his mouth; and when they have beaten him to death, his battered carcass is macerated within his hide which remains unbroken. Then they leave him in the pent-up chamber, and lay under his sides fragments of boughs, thyme, and fresh cassia.

This is done when first the zephyrs stir the waves, before the meadows blush with new colors, before the twittering swallow suspends her nest upon the rafters. Meanwhile the animal juices warmed in the softened bones, ferment; and living things of wonderful aspect, first devoid of feet, and in a little while buzzing with wings, swarm together, and more and more take to the thin air, till they burst

away like a shower poured down from the summer clouds; or like an arrow from the impelling string, when the swift Parthians first begin to fight.

The most superficial knowledge of the life and habits of insects is all that is needed to tell us that the result of this experiment would be the appearance of swarms of flies, not bees, and no one would, today be under the suspicion that they had appeared "spontaneously." In Virgil's time they knew very little about flies.

Much the same mistake is found in Ovid's poem "The Pythagorean Philosophy." Here is part of Dryden's translation of it:

> By this sure experiment we know
> That living creatures from corruption grow:
> Hide in a hollow pit a slaughtered steer,
> Bees from his putrid bowels will appear,
> Who like their parents haunt the fields and bring
> Their honey harvest home, and hope another spring.
> The warlike steed is multiplied we find,
> To wasps and hornets of the warrior kind;
> Cut from a crab his crooked claws and hide
> The rest in earth, a scorpion thence will glide,
> And shoot his sting; his tail in circles toss't
> Refers the limbs his backward father lost;
> And worms that stretch on leaves their filmy loom,
> Crawl from their bags and butterflies become.
> The slime begets the frogs' loquatious race;
> Short of their feet at first, in little space

With arms and legs endued, long leaps they take
Raised on their hinder parts and swim the lake,
And waves repel; for Nature gives their kind,
To that intent, a length of legs behind.

VIEWS OF THE PHILOSOPHERS OF THE MIDDLE AGES.

The cultivation of philosophic speculation and the neglect of accurate observation prevented any change in opinion upon these subjects for centuries. In 1524 Cardan taught that water engendered fishes, and that many animals sprang from fermentation. Van Helmont published explicit directions for the experimental spontaneous generation of mice, and I have no doubt but that mice would be found if his directions were carefully followed. Into the bottom of an earthen crock are placed some grains of barley and wheat, and over them a layer of rags. Then more grains and more rags, then still more grains, and so on until the crock is filled. A cloth is then tied over all, and the whole stood in a dark corner of a cellar for three months. When the crock is removed, large mice will be observed to jump out of it, smaller ones will be found inside near the top, and tiny mice, just beginning to develop, will be found deep down in its contents.

Kirchner went one better, for he tells about and figures in his book, a variety of living things that

he says were formed under his eyes through the transforming influence of water upon the stems of plants. These old ideas that seem so grotesque and ridiculous in the light of modern information, were no more than the natural outcome of lack of knowledge of the life history of the living things considered.

No ancient philosopher seems to have had the hardihood to instruct the poor man how to spontaneously generate a cow, a goat, a fowl or any kind of a creature with which everybody was familiar. When they were under consideration the spontaneous origin was always supposed to have taken place long ago, under conditions that no longer obtain, and there now being plenty of them, no further generation except along well recognized lines occurs.

DECLINE OF THE DOCTRINE OF SPONTANEOUS GENERATION.

The wane of the doctrine of the spontaneous generation of life began with the introduction of exact methods of observation and above all with the adoption of the experimental method of investigation.

This may be dated from the observations of Francesco Redi upon flies and maggots in the seventeenth century.

Until Redi's time—1626-1699—it was generally believed that flies were spontaneously generated in putrefying meat. He placed meat in glass jars, over which he placed netting, and then watched to see what would happen: flies, smelling the meat in the jar, alighted upon the gauze, and upon it they sometimes deposited their eggs or larvæ. No maggots ever occurred in the meat so long as the flies were prevented from getting at it.

Redi came to the conclusion that the maggots were the half developed progeny of the flies, and that flies were not developed spontaneously.

Do not fail to notice that it was by becoming better acquainted with the flies and learning their natural history that Redi came to this conclusion. It has always been so; as soon as the life history of a living thing is completely known, its spontaneous generation ceases to be any longer thought about.

REVIVAL OF THE DOCTRINE WITH THE DISCOVERY OF THE MICRO-ORGANISMS.

But all this had to do with living things large enough to be seen with the naked eye. How about the things that could not be seen? The new world of living things brought to light through the discoveries of Leeuwenhoek, composed of creatures so

small and so simple, seemed not to be the same, and not to be subject to the rules that applied to the larger creatures.

Men who had given up all thought that dogs and mice and birds and fishes were ever developed spontaneously, because they had found out that they were not, now transferred the doctrine of spontaneous generation to the newer and smaller creatures, and about their origin the debate was reopened with all of the old arguments and with many new ones.

With the knowledge we now possess it seems strange that it did not seem to occur to the men of a generation ago that if unfamiliarity with the larger creatures had been the cause of misapprehensions regarding them, unfamiliarity with the newer and smaller creatures might be the cause of similar misapprehensions regarding them. But for a quarter of a century attempts were made to show that the micro-organisms were essentially different from other living things in that they might arise *de novo—i.e.*, spontaneously.

As has already been said, the controversy expired after the last publication of Dr. Bastian, which failed to convince anybody, probably because during the time that he was working upon it, general knowledge of the subject came to exceed his own.

This may seem like a long introduction, and an elaborate discussion of things everybody knows to be untrue, but I introduce it because it will help you to understand the difficulties that attend the growth of scientific knowledge, and because it is necessary to an intelligent understanding of some of the more practical matters that are to come later.

IMPEDIMENTS TO THE ADVANCE OF KNOWLEDGE.

There are probably no greater hindrances to the general progress of knowledge than unfounded popular suppositions and superstitions. The human mind seems to be naturally skeptical. We cling to the opinions of our ancestors "with a kind of antiquarian fondness," even in the presence of the most convincing evidence of their errors.

The view of the majority, whom we willingly acknowledge know less than we, is that to which we incline. A certain amount of conservatism may, perhaps, be a good thing, but the perpetuation of ancient error for sentimental reasons has done inestimable injury to health and happiness by causing people to stand aloof from the best means to those ends.

EFFECTS OF MICRO-ORGANISMS.

In the time of Leeuwenhoek it was observed that yeast contained minute oval bodies only to be seen when the eye was aided by a powerful lens.

In 1838 Latour and Schwann recognized them as

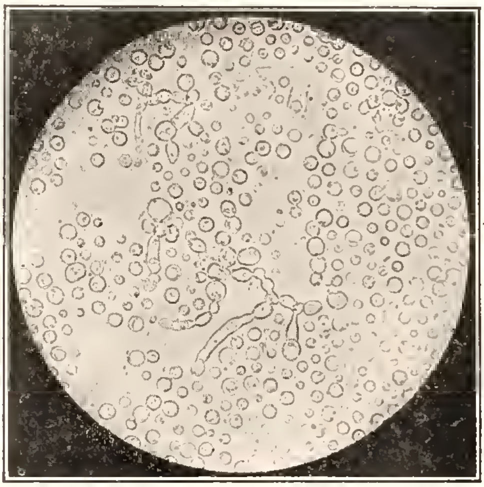


Fig. 5.—Saccharomyces or yeast plant as it appears, alive, under a magnification of 350 diameters. (*Kolle* and *Wassermann*).

little plants, and with newer and better microscopes saw them budding and increasing before their eyes.

Up to that time nobody could at all understand the phenomenon of fermentation. Why would the addition of a little yeast to a fermentiscible solution cause it to ferment? It was very mysterious, but with the discovery that the yeast was alive, and that it consisted of infinitesimally small plants, an explanation was forthcoming. The growth of the

plants could only take place through the abstraction of something from the solution, and in growing the little plants must give off something to the fluid; either of these might be the cause of the fermentation. Moreover, the yeast being composed of the little plants that multiplied, it was now clear how the yeast increased itself, which had not previously been understood.

But when these now universally recognized facts were first suggested they met with a most surprising amount of opposition.

The greatest scientists aligned themselves against them and the great Liebig strenuously maintained that fermentation "was the result of the internal movements which a body in the course of decomposition communicates to other matter whose elements are connected by a very feeble affinity."

DISEASE.

As early as the beginning of the Christian era, a Roman scholar named Varro expressed the opinion that disease might be brought about through the entrance, into the mouth or nostrils, of very minute animals emanating from marshy places. "Si qua loca erunt palustria, crescunt animalia quaedam minuta, quæ non possunt oculi consequi et per aera intus in corpora per os ac nares perveniunt difficiles

morbos." He had no reason, that we can find, for entertaining such a theory, and seems to have arrived at it through philosophical deduction. Through the centuries that followed there are occasional suggestions that disease is probably caused by minute living things, but there was no other reason for thinking so than Varro had—philosophical speculation.

But with the discovery of the world of micro-organisms, by Leeuwenhoek, it became possible to pursue the matter, and it was not long before physicians everywhere were pointing out that micro-organisms were to be found in the morbid discharges and fluxes from the sick. Inevitably came the question were they the effect or the cause of the illness?

The observations and discoveries of Leeuwenhoek greatly impressed a Viennese physician, Marcus Plenciz, who, in 1762, began to assume a causal relationship between the animalculæ and the infectious diseases. He finally arrived at the conclusion that the *materies morbi* of an infectious disease must be some minute and invisible living thing that multiplied in the body of the diseased and then passed to others through the air. He even went so far as to conceive a special form of living virus for each kind of transmissible disease. But he was a thinker and not an investigator, or if the latter, had no means

at his command for the demonstration of the truth of his theory which attracted little attention, and was soon forgotten by his contemporaries as well as his successors, except that now and then it was referred to in condemnation. It is no doubt to him in part that Ozanam referred, in 1820, when he wrote: "Many authors have written concerning the animal nature of the contagion of infectious diseases; many have, indeed, assumed it to be developed from animal substances, and that it is itself animal and possessed of life. *I shall not waste time in efforts to refute these absurd hypotheses.*"

Here was another reason for reviving the old question of the spontaneous generation of life. If these tiny things were not formed there, how did they get there?

But the age of experiment had arrived; men were no longer satisfied to speculate about the matter, and set to work to find out.

THE GERM THEORY OF DISEASE.

The story of this great investigation, of such surpassing importance to mankind, is full of interest and should be known, but it is not possible to do more than give its salient points here.

As early as 1840 a German physician named Henle came to the conclusion that all the evidence

collected went to show that micro-organisms were the cause of disease, and that certain micro-organisms were the causes of particular diseases. More than this, he formulated certain methods of proving it. These became known as Henle's postulates.

HENLE'S POSTULATES.

These principles are now universally accepted, though they were scarcely possible of fulfilment in his own day because of the technical difficulties to be overcome. Here they are:

1. A certain specific micro-organism must constantly be found associated with the disease in question.

2. It must be isolated and cultivated apart from the disease.

3. When introduced into healthy animals, it must reproduce the same disease in the experiment animal, and must occur under the same conditions as in the original case.

Nearly twenty years had to elapse before certain new inventions made it possible to fulfil the requirements, which were then promulgated anew.

A growing passion for scientific investigation set in about the middle of the last century. We may justly describe it as:

THE EPOCH OF EXPERIMENTAL INVESTIGATION.

It was in 1862 that Pasteur published his epoch-making paper, "On Certain Organized Corpuscles Existing in the Atmosphere," and showed that almost everywhere the atmosphere about us contains numbers of the seeds, or more correctly "spores" of micro-organisms, which he believed to be the cause of fermentation and as certainly of disease.

When he explained the latter part of the matter to the Academy of Medicine of Paris, they laughed at him. M. Roux gives the following account of one of his experiences at the Académie de médicine:

Pasteur does not hesitate to declare that microscopic organisms are the common cause of infection in newly delivered women. One day in a discussion on puerperal fever at the Academy, one of his most weighty colleagues was eloquently enlarging upon the cause of epidemics in lying-in hospitals; Pasteur interrupted him from his place. "None of these things cause the epidemic: it is the nursing and medical staff who carry the microbe from an infected woman to a healthy one." And the orator replied that he feared that microbe would never be found. Pasteur went to the blackboard and drew a diagram of a chain-like organism, saying, "There, that is what it is like!" His conviction was so deep that he could not help expressing it forcibly. It would be impossible now to picture the state of surprise and stupefaction into which he would send the students and doctors in hospitals, when, with an assurance and simplicity almost disconcerting in a man who was entering a lying-in ward for the first time, he criticised the appliances, and declared that all linen should be put into a sterilizing stove.

But in 1882 John Tyndall, an English scientist, took up the matter, and in a little book, "Floating Matter in the Air," showed that Pasteur was right in finding the source of fermentation in the "organized corpuscles," and at the same time gave the doctrine of the spontaneous generation of life its final death blow.

A few years before that, Robert Koch, a German physician, had begun to study "The Traumatic Infectious Diseases," or those infections that follow injury and result in "festering" or suppuration, fully supporting the microbic theory of those conditions. In 1882 he published a paper upon the cause of Tuberculosis in which he described the *Bacillus tuberculosis*, and *proved* it to be the cause of tuberculosis or consumption. He also invented a new solid form of culture medium by which the isolation and observation of the micro-organisms could more easily be accomplished. These contributions gave to the study of the micro-organisms a new impetus so that its further progress came with a rush that is bewildering.

Chemists were soon in accord that if micro-organisms were kept out of fermentiscible solutions there would be no fermentation, and that for each kind of fermentation a special kind of micro-organism was required.

Surgeons, led by Sir Joseph Lister, were finding that if micro-organisms were kept out of wounds there would be no suppuration—a morbid process at that time so universal that it was supposed to be

Fig. 6.—Sir Joseph Lister.

This eminent Scotch surgeon, devised the antiseptic method of dressing wounds, the outcome of which has been to make possible many useful operations that our forefathers could not have imagined.

necessary to successful healing, though today it is so rare that its occurrence is rather looked upon as an evidence of carelessness upon the part of the surgeon.

PRESENT ATTITUDE TOWARD MICRO-ORGANISMS.

And so through perfected knowledge of such micro-organisms as were known, the attitude of the whole of the scientific world in regard to them became changed. They were no longer looked upon as the *effects* of the conditions under which they were found, but as the *cause.* And so profoundly did this new belief react upon the scientific mind that a new science, *Microbiology,* has arrived. That part of it that has to do with bacteria, and is therefore known as *Bacteriology,* is of such wide-spread application, that if the various books upon the subject be consulted, it will be found to have become a part of biological science, of medical science, of veterinary medical science, of agricultural science, and of botanical science. Indeed, the last book that came under my observation made it a part of pharmacal science.

UNIVERSALITY OF THE MICRO-ORGANISMS.

All this indicates that micro-organisms in general, and bacteria in particular, are of wide-spread distribution. Indeed, they are everywhere.

They are present in vast numbers in the soil; from it they are carried by the rains into the waters so that nearly all teem with them, and from the soil they are disseminated by the winds throughout the

atmosphere, and from it fall in the form of fine dust upon every kind of object.

It is impossible to escape them. One is scarcely born before they are upon him and in him, and upon and in him they remain not only as long as life endures, but to assist in the destruction of his body after death.

It must not be supposed that they are uniformly distributed; they are most numerous where conditions of micro-organismal life are most appropriate. Where these are favorable they abound by the millions; where less favorable their numbers may be small. Upon the snowy and sterile Alpine mountain tops there are none; they compose nearly one-half of the bulk of the freshly dropped dung of any of the higher animals.

But when conditions of life are not favorable they do not necessarily die. Many of them have a method of tiding over the period of cold or famine by the adoption of a special form, that of the *spore*, which is impervious to the drying effects of the air, can withstand great elevations or depressions of temperature, and in that inactive state, requiring no food, can live almost indefinitely. These spores, in great variety, abound everywhere, and only await favorable conditions to sprout into new micro-organisms.

4

COMMON EFFECTS OF THE PRESENCE OF MICRO-ORGANISMS.

Just to prove how universal the micro-organisms are, let me point out certain commonplace facts perhaps not connected with them in your minds. The expressed juice of apples, called cider, is sweet when it is fresh, but it will not remain sweet; it slowly becomes "hard" from the presence of alcohol. To many this is an agreeable change, for the beverage now has a bite, or as popularly known now-a-days, a "kick." But soon the spicy fluid turns sour, the alcohol evaporates, and eventually the fluid becomes vinegar.

During these changes nothing has been done to the apple juice; they seem to take place spontaneously. But what has really happened is that from the atmosphere, from the cider-mill, from the cask, or from other sources, micro-organisms of different kinds have fallen in. One of them, a yeast, finds favorable conditions at once and effects an alcoholic fermentation, and the cider turns hard; another soon takes precedence over the first, and it sours and becomes vinegar.

In the preparation of dough for making bread, the cook adds a little yeast. Without it the bread would be heavy, and scarcely edible. The yeast plants, however, grow in the dough, filling it with

little bubbles of gas resulting from alcoholic fermentation. If one questions why in this case the yeast must be added, instead of depending upon yeasts in the atmosphere or utensils used in making the bread, the answer is easy. Yeasts do not abound in the atmosphere, and are micro-organisms of short life under adverse conditions, so that one cannot safely rely upon finding them when and where they are needed, but must keep them growing in artificial culture. The yeasts that we purchase at the stores are simply artificial cultures of yeast found useful for this particular purpose.

In the brewing of beer it is also necessary to add a yeast to the decoction of grain that is to be fermented. It is the fermentation of the sugar in the decoction that gives the "kick" to the beer by adding alcohol to it. The greatest care has to be exercised in the brewery, lest the yeast spoil and the beer acquire a bad taste. The spoiling of the yeast is nothing more than the accidental addition from the air, of some new and undesirable micro-organism—a weed—whose presence is detrimental.

The housewife "does up" preserves. In the process they are carefully boiled. If she is careful she also scalds the jars and their lids, and then fills and closes them while they are hot. She may not know why she does this, except that if she does

not, the preserves will "work." But we understand it. Into the preserves, as into the cider, micro-organisms have fallen or will probably fall that will inevitably set up the alcoholic or some other fermentation unless killed by the boiling. Or, if they are killed in the preparation by its boiling, some may be in the jars or on their lids unless they too are sufficiently heated to destroy them.

In spite of all the precautions, however, the preserves do sometimes spoil. That is either because the precautions miscarried somewhere along the line, or because the heating was not long enough continued or carried to a high enough temperature to destroy the germs of life accidentally admitted.

Milk becomes sour if kept. If kept in the cold the souring may be almost indefinitely delayed; if kept in the warm, it takes place very soon.

The explanation is very simple; the souring depends upon the presence of bacilli that multiply quickly in the warm, but slowly in the cold.

HOW THE MICRO-ORGANISMS EFFECT THEIR PECULIAR CHANGES.

If we look more closely at the phenomenon of fermentation, we find that one of the sugars most familiar to us and most easily fermented is dextrose or

as it is commonly called glucose. It has the chemical formula:

$$C_6H_{12}O_6$$

If to a solution of it we add some yeast that has been boiled, nothing happens. If we modify the experiment and use yeast that has been distributed through water and then filtered through a porcelain filter, again nothing happens. But if we add the yeast as we receive it, with its little plants all alive, only a few hours need pass before it is evident that the sugar is fermenting, and the usual evidence of it is the presence in the solution of a large number of minute bubbles of gas. The fermentation proceeds slowly at first, then more and more rapidly, then slowly stops, leaving some of the sugar unchanged if the solution was very sweet in the beginning. If we make an analysis, we find that the bubbles are carbonic acid gas, and in proportion to the quantity of the gas formed, the sugar has diminished. The gas has therefore been formed out of the sugar. The transformation takes place according to this formula:

$$\underset{\text{Dextrose}}{C_6H_{12}O_6} = \underset{\text{Alcohol}}{2\ C_2H_6O} + \underset{\text{Carbonic acid gas}}{2\ CO_2}$$

Here we find that one molecule of the dextrose has been split up into two molecules of alcohol and two of carbonic acid gas.

It will not happen if the solution be kept in the cold, and it will not happen if after the addition of the yeast the solution be boiled.

It is therefore clearly a reaction that depends upon the presence of live micro-organisms. If there were a way of counting them, it would further be found that the number of yeast plants had greatly increased in the meantime.

Now, what were the little plants doing all this time? Nothing but living and multiplying, but to live and multiply and make more yeast plants it was necessary for them to eat something—as we say—and that something they had to get from the sugar solution. It was not upon the sugar itself that they fed, for we find it changed into something else, and not used up as sugar. Here is the secret. To live, the yeast plants did not need the sugar, but something that was in the sugar. To get it they must break up the sugar into something simpler, and to all appearances, to get enough of it they were under the necessity of breaking up a great number of the sugar molecules to get the little they needed. But how could the little plants break up the sugar molecules? We cannot do it. No, but we break up a great number of other more complex molecules in order to get from them the particular simpler molecules we feed to our cells, as we

shall shortly see. We both, the yeast plants and ourselves, accomplish the end by virtue of certain peculiar and precious substances prepared for the purpose, and known as *enzymes.* The particular enzyme of the yeast cells is *zymase*, and is contained in their own substance, does not dissolve out, and is present and active only when the cells are most rapidly multiplying. This explains why dead yeast will not cause fermentation; why filtered yeast will not cause fermentation, and why the sugar solution to which yeast was added, will not ferment after boiling. The function of enzymes, in breaking up complex molecules and for rearranging the more simple compounds into the more complex but different ones of which living substance consists, is a universal phenomenon of life.

The enzymic force by which the foods are broken up into simpler substances is described as *analytic;* that by which these simpler substances are newly combined into the proper substance of the creature being fed, as *synthetic.* Both are accomplished through the activity of enzymes.

Let us see how the matter goes on in our own bodies. If we eat a meal of meat, we can do nothing with the meat as such. We must first subject it to the action of an enzyme of the stomach called *pepsin*, and then to another in the intestine known as

trypsin, by which it is broken up into simpler compounds until finally through all of the transformations effected in the various parts of the digestive laboratory, it reaches the stage of amino-acids, in which form we probably distribute it to our cells.

But when the cells imbibe the amino-acids, they are probably unable to do anything with them in that form, but must continue the analysis, following it by various syntheses until everything is finally used up in the production of heat and force, or is combined into the protoplasm in the cell itself.

So it is with both micro-organisms and larger organisms. All nourish themselves through materials that require elaborate transformations before they become useful. In the case of the potato we followed the photosynthesis as far as the production of starch. What does the potato do with the starch? It cannot be used in that form; it simply stores it up in the tuber that we call the potato, to be used at some future time when food in as useful a form may be difficult for its newly starting shoots to get.

Thus, when the potato tries to grow in the cellar, what is it that the tender shoots are living upon? Notice the potato after some period of such growth and it will be found to have become dark colored and soft—spoiled. The starch that makes it useful

to us for food has largely disappeared. Where has it gone?

The sprouts, through the activity of the enzymes in their cells, have transformed the starch to sugar, and the sugar has been utilized in the formation of the protoplasmic substance of which the long pale shoots are composed.

HOW THE MICRO-ORGANISMS DO US INJURY AND CAUSE DISEASE.

To understand this it is necessary to recall a few of the facts already pointed out. Micro-organisms made cider hard by transforming its sugar into alcohol; later, others soured it by the production of acetic acid; micro-organisms soured milk through the formation of lactic acid; micro-organisms cause butter to become rancid through the formation of butyric acid; micro-organisms sometimes cause preserved ripe olives to become poisonous, because the *Bacillus botulinus*, growing in them, elaborates a toxic substance. The alcohol, acetic acid, lactic acid, butyric acid, and toxin are all products of micro-organismal energy resulting from the action of their enzymes upon the substances upon which they are living. If the micro-organisms happen to be living in us, at the expense of our substance, we may become ill because some of the transformation products

are poisonous. If the transformation products happen not to be themselves injurious, the micro-organism is described as harmless or *non-pathogenic;* if they are harmful, as *pathogenic* or disease producing.

So far as the micro-organisms themselves are concerned, disease production is an accident. It is the accidental result of the varying chemical transformations effected during their activities in the body of the higher creature.

From the paleontological point of view there is good reason to believe that the micro-organisms are among the oldest of living creatures. The comparatively simple materials upon which many of them can live, the extreme simplicity of their structure, and the fact that most of them are aquatic, all point in that direction. If the view be correct, and they were among the first of living things, then, of course, later developed animals and plants found them here as they evolved, ready to enter into and damage them as they are doing at present. That form of "the struggle for existence" must have begun almost with the beginning of life.

The history of those early struggles we can never know, but it is not impossible that some of them are written upon the imperishable records of the geological strata. One method of accounting for the

disappearance of animals that once covered the earth, so large and so strong as to appear forever safe from enemies, is to suppose that they fell victims to micro-organismal foes, as did the "Martians" in H. G. Wells' interesting novel, "The War of the Worlds." You have perhaps read it and recall that the terrible, highly intelligent creatures, resembling gigantic cephalopods, that arrived from the distant planet, enclosed themselves in steel fighting towers, seemed to be invincible as they began devastating the earth and destroying human life by the use of asphyxiating gases, but were most happily and unexpectedly destroyed through the attacks of micro-organismal enemies—bacteria—about which they knew nothing and whose attacks they did not know how to avoid.

In the course of time all of the living creatures unable to survive the attacks of micro-organisms have been killed off, and only their stronger descendents and successors remain, we among them. We still suffer and are not only made ill but frequently killed by them, but enough of us survive to maintain the species, and no doubt the longer we are able to do so the greater will be our chances, though it must not be forgotten that as we evolve greater resisting power, the micro-organisms develop a higher degree of invasive power.

Seeing that it is impossible to avoid micro-organisms, and that they are ever entering into us, and many of them remaining in us, it is inevitable that in the course of time there should have come about some system of association between us and them, based upon the advantage to one or the other.

SYMBIOSIS—PARASITISM.

Such systematic living together constitutes what is technically known as *symbiosis*. It has a number of well recognized forms, of which only two need concern us here. They are *commensalism* and *parasitism*.

The general prevalence of micro-organisms being such that it is never possible to escape them, our survival must have depended upon the evolution of certain means of defence by which to rid ourselves of the greater number as accident determines their entry into us. Miscellaneous bacteria and protozoa are no doubt every day entering into our bodies, to be quickly killed and destroyed. Such accidents have nothing to do with the state of symbiosis. But others not seeming to be in any way inimical, are tolerated and permitted to take up a permanent residence in sheltered parts of our anatomy where they do us no harm, and find conditions of warmth and nutrition favorable to them. These become

commensals—i.e., creatures that live in or upon us but do us no harm—and we become their *hosts.*

But on the other hand, certain micro-organisms finding the conditions of life in the body of a higher creature, more favorable than elsewhere, have so perfectly adjusted themselves to those new conditions that life elsewhere has become impossible. Their subsequent evolution has taken place along lines that necessitate such vital association, and to make it possible, has provided special means for securing it for themselves and their descendents. If the association thus formed results in injury to the higher creature, the symbiosis is called *parasitic* and the micro-organism a *parasite.*

Among higher creatures it is usually quite easy to determine which are and which are not parasites, but among the micro-organisms it may be difficult. In not a few cases we are doubtful whether a damaging micro-organism is a parasite or not; in others, as when the micro-organism adopts some ingenious method of transferring itself or its progeny from one host to another we are quite sure of it.

DOUBTFUL AND TRUE FORMS OF PARASITISM CONTRASTED.

The *Bacillus tetani,* which is the cause of the terrible convulsive disease known as "lock-jaw," is a

common micro-organism of nearly all fertilized soils. From exhaustive study of its habits we are of the opinion that it is a common commensal of herbivorous animals, in whose intestines it lives without doing any harm, and from which it is discharged upon the soil with the dung. Unable to develop

Fig. 7.—Bacillus tetani. × 1000. (*Fränkel* and *Pfeiffer*).
The large round spores in the ends of the bacilli transform the little rods into a drum-stick shape.

in the soil, for reasons later to be made clear, it transforms itself into the spore stage, and awaits the fortunate moment when a browsing animal will pick it up with the food it nibbles, and give it a fresh opportunity to develop into bacilli in the intestine. But if accident admits its spores—through

some wound—into the tissues of some animal or man, they may, if the conditions are appropriate, assume the bacillary form and through the metabolic activity of that state begin the elaboration of the toxin that causes the convulsions and may result in the death of the unfortunate. Very few

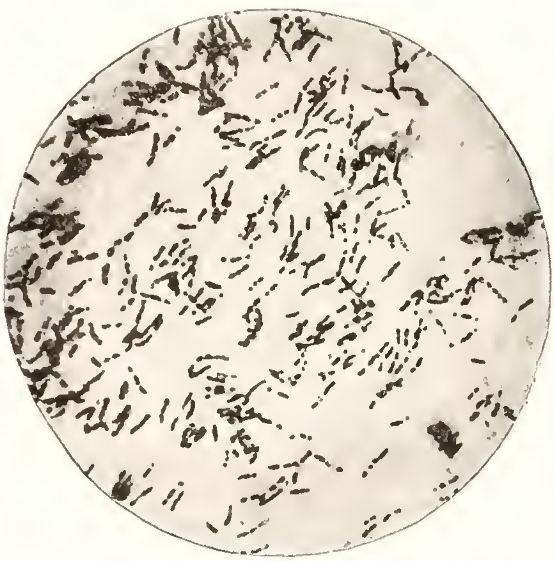


Fig. 8.—Tubercle bacillus in sputum. × 500. (*Fränkel* and *Pfeiffer.*)

The quantity of expectoration represented might be no larger than the eye of a fine needle, yet contain more than 100 micro-organisms. How many would a large mouthful contain?

bacilli can be found in the dead animal's body, there is no way for them to get out of the body and there is no way for them to get into a new body. Is this a case of parasitism? It seems doubtful; it is more like accident.

Let the condition be contrasted with what takes place in tuberculosis. The *Bacterium tuberculosis* is a micro-organism unknown in nature except in the bodies of diseased men and animals. It multiplies in their bodies in great numbers and effects such destruction of the tissues that it is soon escaping in immense numbers in the morbid discharges, from which it finds its way into other men and animals, in which it effects the same changes and escapes to find its way into still others. Here seems to be an endless chain of transmission, and in all probability, a case of true parasitism.

INFECTION.

According to Webster the verb "to infect" means *to taint with morbid matter or any pestilential or noxious substance or effluvium by which disease is produced.* The word has, however, come, by custom, to have a wider application than this definition suggests. In common usage it seems to be synonymous with *contaminate*, which, according to the same authority, means *to soil, to stain, to corrupt.*

When a bacteriologist says that the atmosphere is a source of infection, he does not necessarily mean that it will produce disease; more likely he means that it will contaminate culture media. He is thinking about the various jellies that he makes for the purpose of cultivating the micro-organisms and the difficulty he has in keeping them *sterile*—that is, free from all micro-organisms except those he desires to study.

He knows very well that the atmosphere is full of spores of life that if not carefully denied access to the media will irretrievably spoil it through the growth of weed organisms in which he has no interest.

In the operating room one hears a surgeon say of a dressing, a ligature or a sponge, that it is infected,

under which circumstances he will not use it. That which he really means is that the various objects are contaminated, not having been sterilized; or having been sterilized, have been neglected. In this case, unless they have actually come into contact with the essential cause of disease, it is not certain that they are infected, but if they have been exposed to miscellaneous contaminations there is danger that some of the various micro-organisms adhering to them may be able to cause disease. Therefore the careful surgeon will not use them.

Objects of every kind are usually contaminated, and may be regarded as potential agents of infection unless they have been *sterilized*—that is, subjected to a high degree of heat for the express purpose of killing the attached micro-organisms—and they quickly again become so unless, after the sterilization, they are carefully protected from new contamination.

It is for this reason that all hospitals are provided with outfits of sterilizers through which all materials used in the surgical clinic must be passed.

It is instructive to observe the preparations for a modern surgical operation, and consider what they mean. The skin of the patient, at and near the seat of the operation is shaved, washed with warm water and soap, disinfected with iodine, and then carefully

covered with sterilized dressings in order that as many as possible of the micro-organisms adhering to it may be washed away, others killed, and new ones kept away. The instruments, sutures, ligatures, gauze sponges, towels and instruments to be used by the surgeon, are all wrapped up, sterilized in their wrappings, and kept covered, and thus protected from fresh contamination, until the moment of use. The surgeon puts on a sterilized gown, ties sterilized gauze over his head and covers his face with a sterilized gauze mask in order that nothing may fall from his head or face or escape from his mouth or nose upon the exposed tissues of the wound. The hands he carefully washes, and then covers with sterilized rubber gloves. When everything is thus prepared, he will touch nothing that has not been sterilized, nor will he permit anyone in attendance upon the operation to touch anything that has not been sterilized.

The operation is then begun, and all through its complex details the greatest care is maintained to see that there is no "slip up" in the technic by which the contamination of the wound may be brought about, and the risk of possible infection incurred.

THE OUTER PROTECTIONS OF THE BODY.

All of the ordinary acts of life, such as washing the hands or face, taking a glass of water, soiling the hands with earth while working in the garden, bring sometimes a few, sometimes multitudes of micro-organisms into contact with the outer or inner surfaces of the body. Ordinarily we experience no harm, first, because the greater number of these micro-organisms are harmless; second, because they fall upon the protecting covering of the body, its skin and mucous membranes, through which they cannot penetrate.

Why is it necessary for the surgeon to be so particular about the sterilization of his paraphernalia, and to see that a difficult operative technic is consistently carried out when the rest of us are so careless about what we touch? Because, in every operation, he penetrates these protective coverings, so that any micro-organisms entering through the wound, are at once admitted to the tissues.

DISTRIBUTION OF MICRO-ORGANISMS IN THE NORMAL BODY.

The mouth of every normal human being contains a large number and considerable variety of micro-organisms. The nasopharynx contains more; the crypts or little pockets of the tonsils contain millions

of them. The stomach usually contains very few, if any, because few can endure its highly acid secretion. But the intestine makes up for their absence in the stomach, and the average individual continually carries about a pound of them in his gut.

Numerous varieties and varying numbers are upon the skin, and wherever there is a recess, as at the ears or the umbilicus, greater numbers are apt to be caught and retained.

Does all this imply that the individual is infected? No, according to the usage of the term that we are recognizing, he is contaminated, not infected. We only consider him infected when actual disease producing micro-organisms are brought where they can effect injury. But even then, being infected, he does not necessarily become diseased.

PECULIAR PARADOX OF INFECTION.

It not infrequently happens that some of the micro-organisms accidentally and temporarily present upon or in the body are dangerous, yet no harm results. As has been explained this may depend upon their inability to penetrate the protective coverings. It also occasionally happens that among them may be some well able to penetrate, or that are forced through, and still no ill effects are observed. For example, the bacteriological examination of the

throats of perfectly healthy persons occasionally reveals the presence of true and highly virulent diphtheria bacilli, yet there is no diphtheria. Why? How is it that the individual does not then at once acquire diphtheria? That he may not do so seems to be so paradoxical that it is no wonder that

Fig. 9.—Bacillus of diphtheria as it appears in a small flake of mucus from the trachea. (*Kolle* and *Wassermann.*)

smiling scoffer at all that is true and holy, Mr. George Bernard Shaw, makes a special case of it in one of the interesting medical conversations in his play "The Doctor's Dilemma."

The trouble with Mr. Shaw, and many others who have marvelled about this and other medical matters, is their lack of sufficient information upon the subject. If they knew more they would not experi-

ence the difficulty, as I hope you will not after you have read further.

I shall not answer this interesting question directly; I shall place the means of answering it in your own hands.

A while ago we were discussing the bacillus of tetanus, and learned that when it was admitted to the tissues it caused lock-jaw. Now every one who works in a garden must frequently contaminate his hands with soil in which the spores of the tetanus bacillus are apt to be, but he does not get lock-jaw. No, you will say, that is because he is defended, as you told us, by the skin. Right. But sometimes he works in the same way with cuts or abrasions upon the skin through which the spores can and probably do enter, and yet he does not get tetanus. Understand, the danger is very much greater under these conditions, and he may get it, but ordinarily he does not. Why?

At this point you find yourself "running up against a stone wall." Unless you have knowledge of the subject beyond what I have told you, you cannot answer the question. You find yourself in the position of Mr. Shaw with respect to the diphtheria bacillus about which we will learn presently. But the answer is really very simple to those possessing but a little more knowledge. The tetanus

spores cannot germinate where more than a certain small amount of free oxygen is present. Upon an abraded surface of the skin there is too much, the spores are compelled to remain in the spore stage and can do no injury. If they be carried deeply into the tissue, as by the puncture of a nail—a very common source of tetanus infection of grave character—they reach a depth at which there is much less oxygen and they may be able to germinate. But that they may certainly be able to do so, and cause the terrible disease, it is necessary, as a rule, that they be accompanied into the tissues by some other micro-organisms, not themselves injurious, but with an affinity for the oxygen which is quickly absorbed, thus giving the *Bacillus tetani* the opportunity of growing unrestrictedly and generating its toxin. Now you see that a more intimate acquaintance with the life habits of the tetanus bacillus enables you to understand what at first seemed to be a hopeless paradox.

HUMAN BEINGS ARE NOT ALL ALIKE.

It is usually assumed that people, because they are human beings are all alike. They are alike in the sense that they are sentient beings with one head, two arms and two legs.

But we are not exactly alike; if we were, how could we tell one another apart?

We are physically different to a slight degree; we are mentally, morally and emotionally different to a greater degree, and what is of more importance in this connection, we are chemically different to a considerable degree.

The chemical differences are very interesting. They partly explain why some persons have dark hair and brown eyes, others fair hair and blue eyes. Why some tend to stoutness, others to leanness, and we find that these differences run through whole families.

Some persons are highly susceptible to poisoning by poison ivy; some break out into a rash after eating oysters or other shell fish; others do the same if they eat strawberries; some suffer from asthma if they ride behind horses; some are poisoned by pollens and have rose cold or hay fever; I am made to vomit if I eat honey. Here are a number of marked variations among individuals that can only be referred to chemical differences. They are commonly known as *idiosyncrasies.*

May similar idiosyncrasies or small chemical differences have anything to do with the problems of infection? Can they have any modifying effect upon the behavior of a micro-organism in the body

of an individual? There seems to be no room for doubt about it. I suppose that every reader of this book has suffered from some infectious disease from which others have died. Why should he have recovered while they died? Why did not all die? I am sure that there will be others that have escaped some of the prevalent diseases of childhood, such as chicken-pox, measles or mumps. Why? Oh, well, you may say, I was not exposed in such manner that I took it. That may have been true, but it is not likely. In the past epidemic of influenza did not a great number of individuals escape, without other explanation than that they were fortunate? They were as exposed as others, some of them much more so, as they spent their time looking after those too sick to take care of themselves. Perhaps you have heard that the disease chiefly affected the young, well, what is the difference between youth and age except a chemical one? Some individuals are and some are not susceptible to disease and the difference that makes them so is chemical.

Past experience has shown that when diphtheria breaks out in an asylum or school, everybody does not get it; even when it enters a family, all do not become ill. Like other of the escapes from infection that we have mentioned, it was usually supposed to depend upon the fact that all of the children were

not equally exposed. I do not for a minute intend to have you think that I do not believe that this explains many exemptions, but chemical differences between individuals are of equal importance, as the following shows:

THE SCHICK REACTION IN REGARD TO DIPHTHERIA.

If, with the aid of a very fine hollow needle, a minute drop of sterile diphtheria toxin—the poison produced by the diphtheria bacillus—be introduced between the layers of the skin, we may be able to judge something of the chemical condition of the individual and his susceptibility or resisting power to diphtheria. Understand, the substance employed is harmless in the amount in which we employ it. It is a culture of the diphtheria bacilli, out of which all of the micro-organisms have been removed by filtration, so that only the products remain. It cannot give the individual diphtheria because no bacilli are in it. Now, if a tiny drop of this fluid be introduced, as stated, into the skin, in about one-half of the cases the drop of fluid is absorbed, that is, disappears, and nothing happens. But in the others, a little red swelling appears in the course of a day or so and remains for from seven to ten days. This differing result is found to depend upon the ability

of the members of the first group to resist the irritating effect of the toxin because of something in their bloods, that the members of the other group lack. It is also found that the children that show no reaction usually do not take diphtheria, and that the others may.

Now I am ready to consider Mr. Shaw's paradox, and explain how it is possible for a perfectly healthy person to harbor live virulent diphtheria bacilli in his throat, and yet not have diphtheria or be in any way affected by them. But do I need to explain it? Is it not now so easily understood as to need no explanation? Do you not at once say to yourselves that it must be the result of chemical peculiarity on the part of the individual concerned, by virtue of which he is the fortunate possessor of some substance in his blood that makes the diphtheria bacillus for him a harmless instead of a harmful microorganism?

DIPHTHERIA CARRIERS.

But with the bacilli in his throat one is known as a "carrier," and is *just as dangerous to society as though he was ill and suffering from the terrible sore throat with its yellow-gray false membrane.* and was experiencing the depressing effects of the absorbed toxin. In fact he may be more danger-

ous in these days, for the sick patient is kept at home or in seclusion so that no one may become infected from him, whereas the carrier, not being ill, goes abroad among others who may become infected from him.

There are two kinds of carriers, those who have recovered from a disease and still carry its essential micro-organisms with them, and those not having been ill who unexpectedly and accidentally harbor them. Of the two the latter are the less numerous but probably more dangerous.

CARRIERS OF OTHER INFECTIOUS DISEASES.

After diphtheria, typhoid fever, cholera, pneumonia, cerebrospinal meningitis, erysipelas, and a number of other less well-known infectious diseases, the recovered patient is apt to remain a "carrier" for a longer or shorter time, during which he should not be permitted to mingle freely with his fellows, and during which care should be taken to rid him of the pathogenic micro-organisms. Fortunately in these cases it is comparatively easy to keep him in by warning him that all danger is not yet over. It may be for him, but it is not for others. But having been ill, he is apt to be obedient, remain in, and permit himself to be treated for the extinction of the micro-organisms. But when the carrier has

not been ill, is well, and knows that he is well, the sanitarian has a difficult problem on his hands.

EXPERIENCE WITH CARRIERS AT CAMP BEAUREGARD.

At Camp Beauregard, Alexandria, La., during the preparation for the great war, there was a severe outbreak of cerebrospinal meningitis among the soldiers. In order to stamp it out, a careful bacteriological examination was made of the throat of every one of the twenty-nine thousand men in the camp. Nearly 600 soldiers, themselves well, were found to carry in their throats micro-organisms that could not be differentiated from those causing the disease. They were, therefore, regarded as carriers, sent to a detention camp, and kept from associating with the other men, until repeated examination of their throats showed the micro-organisms to have disappeared. As soon as the sick soldiers were all in the hospital and the carriers all in the detention camp, the epidemic stopped. I think that the explanation is simple. The micro-organism of the disease found three classes of individuals, those in whom it could not live; those in whose throats it could live, but whose defences it could not overcome, and those into whose tissues it readily penetrated so that they became ill, and of whom a large number

died. When the history of the carriers was subsequently gone over, it was found that only one of them had developed the disease.

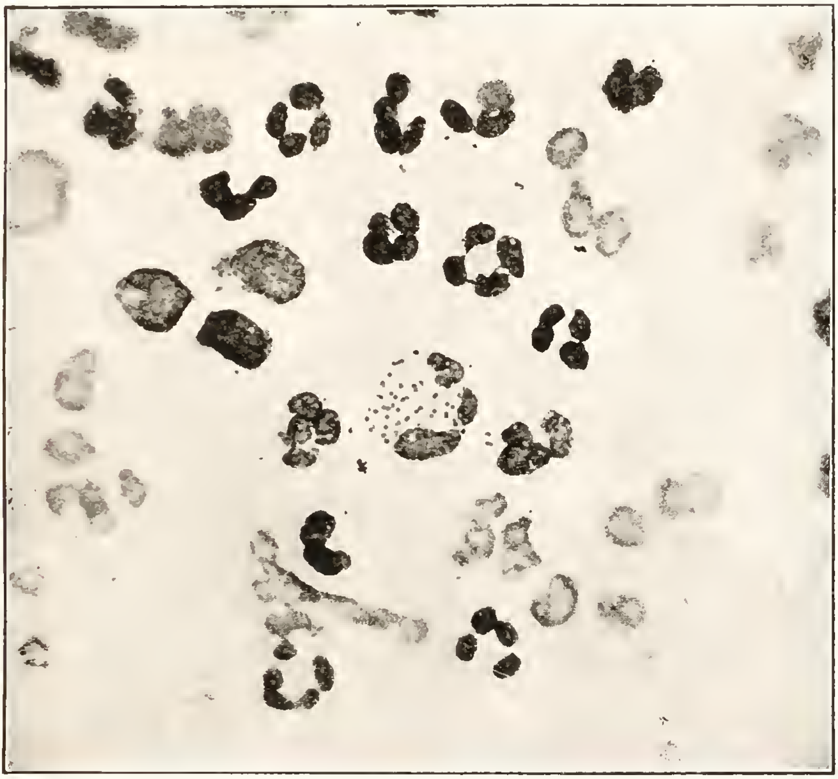


Fig. 10.—The Meningococcus. In the center a group of tiny dots, in pairs, can be seen. They are the meningococci in a white blood corpuscle. (*Hiss* and *Zinser.*)

THE ADMISSION OF INFECTIOUS AGENTS INTO THE BODY.

There are three principal routes by which micro-organisms are admitted to our bodies:

1. By penetration or abrasion of the skin and mucous membranes.

2. By inhalation into the respiratory passages.
3. By being swallowed into the digestive tract.

To the best of our knowledge most of the various micro-organisms causing the infectious diseases of the skin, such as erysipelas, favus, impetigo, ring-worm, acne or pimples, boils and carbuncles, enter the skin directly, either because they are able to penetrate it, or because they are admitted through minute defects in its continuity such as are caused by scratching, shaving, etc.

Those micro-organisms that cause disease of the lungs, such as consumption (tuberculosis), pneumonia, influenza, bronchitis, etc., seem for the most part to be inhaled and thus brought directly into the organs in which their most obvious disturbances are brought about.

Those causing disturbances that center chiefly in the throat, such as diphtheria, tonsillitis, Vincent's angina, etc., may be either inhaled or swallowed, the posterior communication between the nose and mouth bringing them into the pharynx in either case.

Those whose chief disturbances seem to begin or be localized in the intestine, such as the summer diarrhea of babies, typhoid and paratyphoid fever, Asiatic cholera, dysentery, etc., seem usually to be swallowed.

Those causing the venereal diseases result from the admission of their respective micro-organisms into the delicate skin and mucous membranes of the sexual organs, during coitus.

To account for the entrance of the micro-organisms whose chief activities center about or are limited to the central nervous system, such as cerebrospinal meningitis and infantile paralysis, is not so easy. It is generally supposed that they enter either through the mouth or nose, and begin operations in the nasopharynx, from which they extend into the cranial cavity through the thin layer of bone that separates the nasopharynx from the cranial cavity, and which is richly perforated with minute openings that permit the exit of the numerous branches of the nerves of smell—the cribriform plate of the ethmoid bone.

But because a micro-organism enters by some one of these routes, it must not be inferred that its activities must remain limited to the part entered. It easily finds its way into the blood, by which it may later be carried anywhere or everywhere.

When the specific micro-organism of a disease is known, it may be possible to trace its invasion of the body, but if it be unknown, the means of admission of the micro-organism and the course of the invasion may be unknown. Thus, the causes of

measles and scarlatina are not known; we do not know just how infection takes place, but suppose it to be through the nasopharynx, because in both of these diseases there are early disturbances in that region. The causes of small-pox and chicken-pox are unknown—at least not certainly known—and we have no idea how the essential micro-organisms of these diseases enter the body.

TRANSMISSION OF THE CAUSE OF DISEASE FROM INDIVIDUAL TO INDIVIDUAL.

There are two ways by which the essential micro-organisms of disease pass from individual to individual and effect *contagion*. These are usually described as:

1. Direct or immediate.

2. Indirect or intermediate. that is through the aid of fomites or of insect vectors.

A homely illustration will make the difference clear. Instead of thinking of the matter in terms of invisible micro-organisms, let us do so in terms of some larger distinctly visible organism.

If children, one of whom has lice in the hair, play or sleep together, each time the head of one touches that of the other, an opportunity is afforded the lice to pass over, which they seem very willing to do. That is direct transmission.

But if their heads never come together, but the one child puts on the hat of the other, and a stray louse in the hat is thus afforded an opportunity to enter the hair, it is indirect transmission; the hat is the vehicle of transmission, or as it is called, the *fomes*.

If in imagination you now diminish the transferred creature from the size and visibility of the louse to the minuteness and invisibility of a coccus or bacillus, the same conditions may obtain.

The future success of the transmitted louse depends upon its getting a good foot-hold. If it catches in the hair, it is safe, and if it be a gravid female, proceeds to fasten its eggs to the hairs, and soon the head teems with parasites. If, however, it arrives upon the smooth skin where there are no hairs to hold on to, it may be brushed off and lost.

Of course I need not point out to you that if the louse should be swallowed, it would certainly be destroyed by digestion, and never could reach the hair. If it should be inhaled, it could not reach the hair, but alive or dead, as a foreign body might damage the lungs in quite an unexpected and unnatural way. Here we have an example of the importance it is to the organism to reach the body through appropriate avenues if its usual activities are to be continued.

DIRECT INFECTION VIA THE SKIN.

If full benefit be derived from the illustration, you will perceive that the clothing worn by one person and then by another may not only transmit lice, but also any micro-organisms that may have been

attached to it, and if it contained lice, any micro-organisms they may harbor as the result of having sucked the blood of an ill person. The latter fact is of importance in connection with the known method of infection with typhus fever. It is by no means unusual for the poor to sell, and the better off to give away, the clothing of a recently deceased member of the family. In times of epidemic it is a very dangerous thing to permit, as any infectious agents go with it. The clothing, especially the underclothing, of any one that has suffered from a transmissible disease ought to be carefully disinfected before being worn again, unless it be known that the micro-organisms of the particular disease are incapable of remaining alive upon it or of being thus transmitted.

In certain skin diseases the patient not infrequently reinfects himself from his own clothing.

A soldier of my acquaintance, while in the army, contracted one of the common forms of ring-worm. He was discharged in the spring of the year, consulted his doctor, and soon was cured of the disease. But with the advent of the cold weather, the following autumn, again put on the underclothing he had worn as a soldier, and soon suffered a relapse of the skin disease. The explanation was very simple. The micro-organisms of that disease formed spores

with strong resisting powers, and when he again brought them into contact with his skin they at once began to grow and invade.

I was recently told of a man who had recovered from an attack of ring-worm of the toes. Long afterward he suffered from a relapse that was successfully traced to a pair of straw bath slippers he had worn while suffering from the original attack.

Many other means for the easy spread of skin diseases through indirect transmission will occur to you. We all are occasionally obliged to sleep in hotel beds, wash at public basins, dry our hands upon public towels, dress the hair at the club with brushes used by every comer, or have it dressed by the barber with brushes used for everybody.

In otherwise carefully conducted households there is not infrequently a community of interest in sponges, flesh-brushes and towels. All of these serve as means of interchange between the skins of different persons. So long as all are free from communicable skin affections, there is no danger, but let there be one such case, and the disease may soon be communicated to all, and in public places one can never tell who was his predecessor or from what disease he suffered.

But perhaps, you will say, you are overrating the dangers for the towels, sheets and pillow-cases are

always freshly washed before being used by a newcomer. Yes they are—at least let us hope that they are—but unless done in boiling water, the mere washing does little good.

This is well shown by what happens where, as in some parts of the Philippine Islands, the washing is done in cold water. Many of those remaining for any length of time become infected and suffer as long as they remain, with a mild form of skin disease—ring-worm.

DIRECT INFECTION VIA THE MUCOUS MEMBRANES.

But the affections of the skin are, in general, of trivial importance compared with those that result from the transmission of micro-organisms from mucous membrane to mucous membrane. As the direct contact between mucous membranes implies a very intimate personal association, it might be inferred that fewer opportunities for it are possible, and that therefore fewer cases of disease so arise. That is a mistake. The very nature of the contact is such as to make the transmission almost inevitable.

There are two such contacts to which careful consideration must be devoted: that of the lips, and that of the sexual organs. In each the most delicate tissues are brought into apposition and interchange of secretion permitted.

Remembering that those who have suffered from attacks of infectious disease commonly carry the micro-organisms of those diseases with them for a variable length of time, and that a few who have not been themselves diseased may be carriers of the micro-organisms by which others may be made ill, it is easy to understand that in all promiscuous contacts of these kinds there is distinct risk. It is neither possible nor necessary to offer statistical proofs of so plain a matter as this. We can never know how frequently disease is transmitted by kissing, but upon theoretical evidence it may be accepted as a very common mode of infection. If you will but remember what has been said about the occurrence of the micro-organisms of influenza, pneumonia, diphtheria, cerebrospinal meningitis, measles, scarlatina, whooping-cough, etc., in the mouths of those who have recovered from the respective affections, and the discharge of the bacilli of tuberculosis through the mouths of those suffering from consumption, as well as what has been said about the diphtheria and cerebrospinal meningitis carriers who are and have been well, you cannot but come to the conclusion that mouths are so commonly contaminated and infected that they should not be brought together as a common mode of salutation. Promiscuous kissing ought to be abandoned.

The diseases transmitted through the contact of the sexual organs are fortunately few in number. but unfortunately are extremely contagious. very dangerous. and very prevalent. When one party is infected, the other can scarcely escape. Promiscuous sexual intercourse is above all things to be avoided. Those ready to indulge in it, have in all probability already indulged in it, and are therefore apt to be already diseased. They are moreover usually of a character not to be believed in their declaration of health any more than in their declarations of chastity.

Many thoughtless young men and women, and many reckless older ones, have indulged themselves sexually to find out when too late, that the brief enjoyment has resulted in their becoming the victims of maladies of far-reaching importance, socially and domestically, as well as being very difficult to cure.

DROP INFECTION.

Direct transmission of micro-organisms from individual to individual may take place without direct contact in what is known as "*drop infection.*" It is the result of the discharge of the infectious agents from the nose or mouth of the patient during coughing or sneezing and their inhalation by his neighbors.

We are beginning to believe that this is the most frequent mode of infection in those diseases in which the essential micro-organisms are so situated that they can thus be discharged. It is thus that we, at present, account for most cases of consumption (tuberculosis), pneumonia, whooping-cough, influenza, measles, and other diseases in which there is cough.

Knowledge of it shows the importance of teaching every person, well or ill, to make a practice of covering the mouth with the handkerchief during coughing or sneezing. One may be well and think there is no danger, but may be a carrier, and for the sake of his companions ought to take this slight precaution, which is no more than polite society already demands.

It was to prevent drop infection that the health authorities of San Francisco, during the recent influenza epidemic, encouraged the people to go about with the nose and mouth covered with masks of antiseptic gauze. The micro-organisms caught upon the gauze, both coming and going. If one already had them in his own nose and throat, he could not disseminate them, because they were kept in by the gauze; on the other hand, if his neighbor had them and coughed at him, they were kept out by the gauze.

THE INDIRECT TRANSMISSION OF DISEASE BY FOMITES.

The indirect transmission of micro-organisms from the nasal and oral passages of one individual to those of another may also be common. In all probability the greatest transgressor in this particular is the pocket-handkerchief. What shall we say of the disgusting but common custom of using the parents' handkerchief to wipe a baby's nose, and then later the noses of the other children? Is it any wonder that contagious diseases run through families.

Spoons, forks, cups, glasses, napkins, and other objects that pass from mouth to mouth, at home and abroad, without adequate washing or disinfection, may be sources of transmission.

Children commonly have lead pencils in common and are apt to moisten them with saliva to make the marks blacker; they blow one another's whistles, trumpets, mouth organs, jew's-harps, and effect exchanges of saliva in innumerable ways that it requires constant vigilance to determine or avoid.

Men and boys not infrequently smoke one another's pipes, and play one another's wind instruments. Mechanics sometimes make a practice of filling the mouth with the nails or pegs they are about

to use, taking them from the tool box regardless of their having been in the mouth before.

If all were well these things would not matter. But who is well? You never can tell. You cannot even be sure that you are well yourself. Yesterday I was apparently in the best of health; today I have a cold. Was I well yesterday when I so thought? Very likely not. In all probability I was then already carrying the micro-organisms of the cold with me, and might have passed them on to another without dreaming of it. And curiously, the very time at which some diseases—measles, for example—are most readily transmitted, is before the recognizable symptoms appear.

THE FILTHY HUMAN HAND.

Many are of the opinion that there is no worse offender than the human hand in the transmission of disease producing micro-organisms from man to man. Refined persons take pride in keeping their hands "clean." But what they know as clean is not so in the bacteriological sense. No hand, is, or can be, bacteriologically clean unless it has just been scrubbed and thoroughly disinfected, after which it will not remain so for one moment under ordinary circumstances. But even when carefully disinfected, a hand is so apt to retain some micro-organisms

upon it, that surgeons no longer regard hands as capable of disinfection, and cover them with sterilized rubber gloves, before they operate, lest they introduce micro-organisms into wounds with their fingers. It is only the most obvious and visible "dirt" that is ever removed from the average hand.

Hands not only touch every conceivable external object, but are brought into frequent contact with the various openings of the body from which they must inevitably gather up nasal, oral, urinary and fecal micro-organisms, harmless or harmful. With hands thus bacteriologically soiled, we greet one another with a friendly but doubtless sometimes injurious hand-shake.

If it has ever been your privilege at a large reception to welcome a great number of guests, you must have been impressed by the different qualities of their hands, and after receiving and shaking all kinds—clean, dirty, warm and moist, cold and dry—have been glad when you could hurry away to get rid of the results through a liberal use of warm water and soap. No wonder that men who are often compelled to hold large receptions wear gloves! Strange etiquette that requires that on ordinary occasions the gloves be removed before the hand is given. It removes the only safeguard one has from the invisible enemies that lurk in the

skin. And what a vicious custom it is to hold the hand before the mouth during a cough, and then shake hands with someone immediately after!

But it is not only in shaking hands that the micro-organisms are passed along. It is with the hands that all the foods that come to market and are prepared in the kitchen, are touched. What effect this may have may be understood by an inquiry into the typhoid carrier's hand.

THE TYPHOID CARRIER'S HAND.

In the course of typhoid fever, the bacilli multiply in the intestine. From it they sooner or later enter the lymphatics and eventually reach the blood, by which they are distributed all over the body. Almost immediately, they begin to be eliminated through the natural emunctories, one of which is the liver. They thus reach the bile, the excretion of the liver, and with it commonly get into the gall-bladder. Now as the course of the disease is run, the bacilli become fewer and fewer in the intestine, entirely disappear from the blood, no longer are in the bile, and lastly disappear from the intestine, except in the case of the unfortunate carriers. In these individuals those of the bacilli that reach the gall-bladder seem to find its contents and shelter salubrious, and there they remain sometimes for months.

sometimes for years, sometimes as long as the patient continues to live. Now and then the gall-bladder partly empties itself, discharging its bile, together with its contained bacilli into the intestine. At such times the intestinal discharges become infectious.

Under these circumstances toilet paper, though a luxury and an excellent cleansing medium, is no guard against the typhoid bacillus, and every time the carrier is called upon to use it, he contaminates his hand with the infectious and pathogenic micro-organisms. No ordinary washing, as has been shown, will remove the bacilli, and upon the hand they remain until eventually worn away through contact with the various objects handled during the course of the day, upon which they are distributed. And what if these handled objects are the foods that others shall eat?

They may be contaminated by the carrier unknowingly and unavoidably.

Would you be as willing to eat food if you knew that it had been previously handled by a typhoid carrier? Would you be as willing to shake hands with one if you knew it?

What in this country is true of typhoid fever, is equally true, in other countries, of cholera and dysentery. Each disease has its carriers.

Carriers of diphtheria, tuberculosis, influenza, cerebrospinal meningitis, and other diseases threaten us on all sides. This is not chimerical; it is no exaggeration; it is fact. I do not mention it to cause you to cease from greeting your friends or enjoying your food, but to impress you with the difficulty of avoiding infection, and to enable you to understand that sanitarians recognize such sources of infection and are doing what is possible to eliminate them.

BEHAVIOR OF THE ANCIENTS TOWARDS CONTAGIOUS DISEASES.

We have no idea when ancient peoples first began to recognize that they "caught" diseases from one another, and that to escape them it was necessary to keep away from those who had them. Thought upon the subject seems to have been different among different peoples at the same period. In the fifth chapter of the Second Book of Kings, we are told that Naaman, the general of the Syrian armies was a leper, and was sent to the king of Israel with letters asking that he cure him.

There is nothing in the account to make us believe that he was held in low esteem or separated from his fellows on this account. Whether at the same time leprosy was similarly regarded by the

Jews cannot be determined, but in their law, as it came to be interpreted later, lepers were greatly feared, and very strictly segregated from the people in general. Especially was this true in New Testament times, if the accounts given by Lew Wallace in "Ben Hur" are trustworthy. Gustav Flaubert in his historical romance "Salambo" represents the Carthagenian patrician and general, Hanno, as suffering from leprosy at an advanced stage, and hideously disfigured, yet living in his own home, associating with his fellow townsmen, conducting political negotiations, and even leading armies to battle.

In passing, it is interesting to note that lepers are variously dealt with at the present time. In some places they are most carefully segregated, in others they are permitted to mingle with other people. The explanation is to be found in the fact that though the cause of the disease is well known, no one understands how it is transmitted.

For centuries after it was fully recognized that certain diseases were communicable and that we "got them from one another," the measures taken for preventing them were very ineffective because not enough was known about their causes and transmission to enable scientific measures to be instituted. The same general rules were supposed to apply to all cases; some times they succeeded, some-

times they failed. They were frequently destructive to property and apt to be very expensive. But those in authority did what they could, and we, today do no more. Where present knowledge is equal to the emergency we succeed, where not, we fail. We succeed in keeping out yellow-fever, typhus fever, plague and cholera because we understand the means of transmission and spread; but how we failed in the case of influenza whose cause we do not know, and whose means of transmission has not been found out!

THE INDIRECT TRANSMISSION OF MICRO-ORGANISMS BY INSECT VECTORS.

VIEWS UPON TYPHUS FEVER HELD AS LATE AS 1905.

From time to time reference has been made to typhus fever. It is rare in this country, but epidemies of it have from time to time occurred. when it has been variously described as ship fever. jail fever, spotted fever, camp fever, hospital fever, etc. It resembles typhoid in that it is a febrile disease with an eruption of small rose-colored spots, but is unlike it in that it comes on more quickly, runs a much shorter and commonly more fatal course. The cause of the disease has not yet been certainly determined. In Osler's Practice of Medicine, edition

of 1905, can be found the best information on the subject in the knowledge of the profession at that time. This is what it says:

> Typhus is one of the most highly contagious of febrile affections. In epidemics doctors and nurses in attendance upon the cases are almost invariably attacked. There is no disease that has had so many victims in the profession. It is stated that in a period of twenty-five years, among 1230 physicians attached to institutions in Ireland, 550 succumbed to the disease. . . . Bedding and clothes retain the poison for a long time. . . . It attaches itself particularly to the bedding and linen and to the furniture of the room, and appears to retain its activity for a remarkably long time. To catch the disease there apparently must be fairly intimate contact with the patient, more particularly with a large number of patients. Thus in mild outbreaks of only a few cases, physicians and nurses are rarely affected, while in severe epidemics, all in attendance may be attacked. Nothing has yet been determined as to the nature of the specific virus.

PRESENT DAY VIEWS UPON TYPHUS FEVER.

Typhus fever now rages as it has done since early in the great war, in a number of the countries of Southeastern Europe. Great numbers of doctors and nurses in the service of the Red Cross are in attendance upon the patients, but it is exceptional for them to contract the disease. The difference between the former great, and present diminished, danger has been brought about not through the discovery of the specific micro-organism, for that has

still eluded us, but through the discovery of what is of equal importance, the means by which the disease is spread. The investigations of Nicolle, Couer and Conseil in France, of Goldberger and Anderson in this country, and of Ricketts and Wilder in Mexico, beginning in 1909, have definitely proved that the disease is transmitted through the bites of infeeted lice. If the lice are prevented from passing from patient to doctor or attendant, there is no transmission of the disease. The disease is not eontagious in the ordinary sense; it cannot be caught from the patient; it is indirectly transmitted to others by the bites of infected lice.

It is now easy to explain the peculiarities of transmission pointed out by Dr. Osler. It is the facility with which the lice pass from the patient to the doctors or nurses that explains the whole thing. With a small number of cases there are few opportunities; with a large number, as in an epidemic, they become multiplied. In epidemics there is usually scarcity of clothing and bedding which are used again and again without sufficiently thorough washing to get rid of the lice.

At one time if a vessel with typhus fever on board had come into an American port, the people of the city would have been alarmed; today they frequently arrive at New York, but the news-

papers fail to take particular notice of it. No one now fears typhus if he is in a position to take the proper precautions. The only reason that the disease continues to rage in the East is because of the universality of lice among the poor and unwashed populations.

YELLOW FEVER.

Matthew Carey published, in 1830, a vivid description of the greatest of the northern epidemics of yellow fever, which occurred in the city of Philadelphia, then the capital of the United States, during the months of August, September, October and November of 1793.

His "Short Account of the Malignant Fever, Prevalent in the Year 1793, in the City of Philadelphia," will enable the reader to appreciate the effect of the epidemic upon the inhabitants:

> It was some time before the disorder attracted public notice. It had, in the meanwhile swept off many persons. . . . The removals from Philadelphia began about the 25th or 26th of August [1793]: and so great was the general terror, that for some weeks, carts, wagons, coaches, gigs and chairs, were almost constantly transporting families and furniture to the country in every direction. Many people shut up their houses wholly; others left servants to take care of them Business became extremely dull. Mechanics and artists were unemployed; and the streets wore the appearance of gloom and melancholy.

Thus far one cannot help observing the correspondence between what took place in London during the great plague epidemic and these happenings in Philadelphia during the yellow fever epidemic. But the time and place make no matter; wherever a severe epidemic rages, the well people try to escape infection by running away, and as a matter of fact, many of them do so escape.

The first official notice of the disorder, was on the 22d of August, on which day the Mayor of Philadelphia, Matthew Clarkson, Esq., wrote to the City Commissioners: and after acquainting them with the state of the city, issued most peremptory orders, to have the streeets properly cleaned and purified by the scavengers, and all filth immediately hauled away. These orders were repeated on the 27th, and similar ones given to the clerks of the market.

The 26th of the same month, the College of Physicians had a meeting, at which they took into consideration the nature of the disorder, and the means of prevention and cure. They published an address to the citizens signed by the president and secretary. . . .

Here let us pause to remark how, with the best intentions in the world, they recommended measures of no earthly value, but which were quite in keeping with the state of knowledge at the time. As valueless recommendations might be made today were we not in possession of exact knowledge of the means by which the disease is spread, or if the disease were one, like influenza, about which knowledge is still uncertain.

. . . to avoid all unnecessary intercourse with the infected; to place marks on the doors or windows where they were; to pay great attention to cleanliness and airing the rooms of the sick; to provide a large and airy hospital in the neighborhood of the city for their reception; to stop the tolling of the bells; to convey to the burying ground, those who died of the disorder, in carriages, and as privately as possible; to keep the streets and wharves clean; to avoid all fatigue of body and mind, and sitting or standing in the sun, or in the open air; to accommodate the dress to the weather, and to exceed rather in warm than in cool clothing; and to avoid intemperance; but to use fermented liquors, such as wine, beer and cider, with moderation. They likewise declared their opinion, that fires in the street were a very dangerous, if not ineffectual, means of stopping the progress of the fever, and that they placed more dependence on the burning of gun-powder. The benefits of vinegar and camphor, they added, were confined chiefly to infected rooms; and they could not be too often used on handkerchiefs, or in smelling bottles, by persons attending the sick.

In consequence of this address, the bells were immediately stopped from tolling. The expediency of this measure was obvious; as they had before been almost constantly ringing the whole day so as to terrify those in health, and drive the sick as far as the influence of imagination can produce that effect to their graves. An idea had gone abroad, that the burning of fire in the streets, would have a tendency to purify the air, and arrest the progress of the disorder. The people had, therefore, almost every night, large fires lighted at the corners of the streets. The 29th, the Mayor, conformably with the opinion of the college of physicians, published a proclamation, forbidding this practice. As a substitute, many had recourse to the firing of guns, which they imagined was a certain preventive of the disorder.

This was carried so far, and attended with such danger, that it was forbidden by an ordinance of the Mayor.

The 29th, the Governor of the state wrote a letter to the Mayor, strongly enforcing the necessity of the most vigorous and decisive exertions "to prevent the extension of, and destroy the evil." . . . The number of the infected daily increasing, and the existence of an order against the admission of persons laboring under infectious diseases into the Alms House, precluding them from a refuge there, some temporary place was requisite; and three of the guardians of the poor, about the 26th of August, took possession of the circus, in which Mr. Ricketts had lately exhibited his equestrian feats, being the only place that could then be procured for the purpose.

Thither they sent seven persons afflicted with the malignant fever, where they lay in the open air for some time, and without any assistance. Of these, one crawled out in the commons, where he died at a distance from the houses. Two died in the circus, one of whom was seasonably removed; the other lay in a state of putrefaction for above forty-eight hours, owing to the difficulty of procuring a person to remove him. On this occasion occurred an instance of courage in a servant girl, of which at that time few men were capable. The carter, who finally undertook to remove the corpse, having no assistant, and being alone unable to put it in the coffin, was on the point of relinquishing his design, and quitting the place. The girl perceived him, and understanding the difficulty he labored under, offered her services, provided he would not inform the family with whom she lived. She accordingly helped him to put the body into the coffin, though it was by that time, in the most loathsome state of putrefaction. It gives me pleasure to add, that she still lives, notwithstanding her very hazardous exploit.

The inhabitants of the neighborhood of the circus took the alarm, and threatened to burn or destroy it, unless the

sick were removed; and it is believed they would have actually carried their threats into execution, had compliance been delayed a day longer.

The 29th, seven of the guardians of the poor had a conference with some of the city magistrates on the subject of the fever, at which it was agreed to be indispensably necessary, that a suitable house, as a hospital, should be provided near the city, for the reception of the infected poor. . . . Conformably with these resolves, a committee of the guardians was appointed, to make inquiry for a suitable place; and on due examination they judged that a building adjacent to Bushhill, the mansion house of William Hamilton, Esq., was best calculated for the purpose. . . . [Bushhill was situated near the present intersection of 16th and Buttonwood Streets, but then quite "out of town."]

Shortly after this, the guardians of the poor for the city, except James Wilson, Jacob Tomkins, Jr. and William Samsom, ceased the performance of their duties, nearly the whole of them having removed out of the city. . . .

The whole care of the poor of the city, the providing of Bushhill, sending the sick there, and burying the dead, devolved, therefore, upon the above three guardians.

The consternation of the people of Philadelphia, at this period, was carried beyond all bounds. Dismay and affright were visible in almost every person's countenance. Most of those, who could, by any means, make it convenient fled from the city. Of those who remained, many shut themselves up in their houses, being afraid to walk the streets. The smoke of tobacco being reported as a preventive, many persons, even women and small boys, had cigars almost constantly in their mouths. Others, placing full confidence in garlic, chew it almost the whole day; some kept it in their pockets and shoes. Many were afraid to allow the barbers or hair-dressers to come near them, as instances had occurred of some of them having shaved the dead, and many having engaged as bleeders. Some who car-

ried their caution pretty far, bought lancets for themselves, not daring to allow themselves to be bled with the lancets of the bleeders. Many houses were scarcely a moment in the day, free from the smell of gun-powder, burned tobacco, nitre, sprinkled vinegar, etc. Some of the churches were almost deserted, and others wholly closed. The coffee house was shut up, as was the city library, and most of the public offices—three out of four daily papers were discontinued, as were some of the others. Many devoted no small portion of their time to purifying, scouring and whitewashing their rooms. Those who ventured abroad, had handkerchiefs or sponges, impregnated with vinegar or camphor, at their noses, or smelling-bottles full of thieves' vinegar. Others carried pieces of tarred rope in their hands or pockets, or camphor bags tied around their necks. The corpses of the most respectable citizens, even those who had not died of the epidemic, were carried to the grave on the shafts of a chair, the horse driven by a negro, unattended by a friend or relation, and without any sort of ceremony. People uniformly and hastily shifted their course at the sight of a hearse coming towards them. Many never walked on the foot-path, but went in the middle of the streets, to avoid being infected in passing houses wherein people had died. Acquaintances and friends avoided each other in the streets, and only signified their regard by a cold nod. The old custom of shaking hands, fell into such general disuse, that many shrank back with affright at the offer of a hand. A person with a crape or any appearance of mourning, was shunned like a viper. And many valued themselves highly upon the skill and address with which they got to the wind-ward of every person they met. Indeed it is not probable that London, at the last stage of the plague, exhibited stronger marks of terror, than were to be seen in Philadelphia from the 25th or 26th of August, till late in September [1793]. . . . Never, perhaps, was there a city in the situation of Philadelphia at this period.

The President of the United States, according to his usual custom, had removed to Mount Vernon with his household.

At the meeting on Sunday, September 25th, a circumstance occurred, to which the most glowing pencil could hardly do justice. Stephen Girard, a wealthy merchant, a native of France, and one of the members of the committee, sympathizing with the wretched situation of the sufferers at Bushhill, voluntarily and unexpectedly offered himself as manager, to superintend that hospital. The surprise and satisfaction excited by this extraordinary effort of humanity can be better conceived than expressed. Peter Helm, a native of Pennsylvania, also a member, actuated by the like benevolent motives offered his services in the same department. Their offers were accepted, and the same afternoon they entered on the execution of their dangerous and praiseworthy office.

. . . .

On the 16th, the managers of Bushhill, after personal inspection of the state of affairs there, made report of its situation, which was truly deplorable. It exhibited as wretched a picture of human misery as ever existed. A profligate abandoned set of nurses and attendants (hardly any of good character could at that time be procured), rioted on the provisions and comforts prepared for the sick, who (unless at the hours when the doctors attended) were left almost entirely destitute of every assistance. The sick, the dying and the dead, were allowed to remain in the most offensive state imaginable. Not the smallest appearance of order or regularity existed. It was, in fact, a great human slaughter house, where numerous victims were immolated at the altar of riot and intemperance.

It is not intended to go into details regarding the management of this epidemic, or the hospital made necessary by it, but it is impossible not to quote

Carey's last paragraph in appreciation of the work of its managers:

> Before I conclude this chapter, let me add that the perseverance of the managers of that hospital has been equally meritorious with their original magnanimous beneficence. During the whole calamity at this time, they have attended uninterruptedly, for six, seven, or eight hours a day, renouncing almost every care of private affairs. They have had a laborious tour of duty to perform. Stephen Girard, whose office was in the interior part of the hospital, has had to encourage and comfort the sick—to hand them necessaries and medicines—to wipe the sweat off their brows—and to perform many disgusting offices of kindness to them, which nothing could render tolerable, but the exalted motives that impelled him to this heroic conduct. Peter Helm, his worthy coadjutor, displayed, in his department, equal exertions, to promote the common good.

In the light of knowledge now at hand it is amusing to read that Dr. Benjamin Rush, in his time the most distinguished physician of the city, attributed the epidemic to "damaged coffee that putrefied on a wharf near Arch Street."

The population of Philadelphia, at that time was about 40,000, and 4041 persons died—a death-rate of more than 10 per cent.

Since 1793 there have been numerous other epidemics of yellow fever in the United States, and in each case the utmost anxiety was felt lest the disease spread over the whole country. In a considerable epidemic in 1897, in which the disease spread

through all the Gulf States, such excitement was felt in adjoining states, that travel and commerce between them was interrupted by armed guards at the railroad stations who refused to permit passengers to leave the trains or merchandise to be unloaded.

My colleague, Prof. Allen J. Smith, of the University of Pennsylvania, was at that time in Texas, and has told me that only those who have lived through such an epidemic can understand the extent of the consternation felt by the people. One of his personal friends who was unfortunate enough to be called to see one of the first cases, was burnt in effigy for declaring that the sick man had yellow fever. Other men who confirmed the diagnosis had their medical practices ruined.

CHANGE IN THE ATTITUDE OF THE PUBLIC TOWARD YELLOW FEVER.

But now yellow fever is little feared, and there is a reasonable probability that it may soon cease to exist. Here are the reasons: In 1900 a commission of medical officers of the United States Army, consisting of Drs. Reed, Carroll, Lazear, and Agramonte was sent to Cuba for the purpose of investigating the disease, and following a clue supplied by Dr. Charles J. Finlay, were successful in discover-

ing that it is transmitted from man to man through the bites of certain mosquitoes (Stegomyia). Not only did they prove that, but they also showed that there is no other means by which it can spread. No kind of an association with the patients caused con-

Fig. 11.—Dr. Charles J. Finlay, of Havana, who spent many years trying to prove that the transmission of yellow fever was effected by the bite of the Stegomyia mosquito. He was right though his experiments were inconclusive.

tagion, no kind of contact with fomites could do it. Some of the men interested in the experiment even went so far as to sleep in beds in which yellow fever patients had just died, and to do so in the very night clothes that the deceased had worn at the time of death, some of which were soiled with the black vomit of the disease. In no case did infection occur.

More detailed information upon this subject will be given later. That which is to be emphasized here is that, as the result of the information thus gained by study and experiment, the whole attitude of the professional and lay mind has been changed. Commerce need not be interrupted, nor any property destroyed. The prevention of the disease becomes simply a campaign against mosquitoes.

MEANS OF PREVENTING AND COMBATTING EPIDEMIC DISEASES.

Infectious diseases do not arise from nothing. They do not generate spontaneously any more than do the micro-organisms that cause them. They all exist, all the time, somewhere, either in epidemic, or in endemic form. Nearly all epidemics can be traced to certain endemic centers, the so-called "home of the disease," from which it is distributed by commerce, by migration, by the movements of armies, by religious pilgrimages, or by some other recognizable means.

Dr. Simon Flexner has expressed the belief that the future prevention of the great epidemics must be international and that the proper place to begin this extermination is in the natural endemic centers, and the proper time to begin is before an epidemic outbreak occurs. If through international agree-

ment and co-operation that could be achieved, it might be possible to realize the dictum of Pasteur that, "it is in the power of man to cause infectious diseases to disappear from the face of the earth."

Our forefathers suffered from epidemic diseases whose advent was mysterious, and whose causes were unknown. We are rarely in the same position. Long before the disease appears we know that it is coming and that we must do something to prevent it. If we read in the morning paper that cholera has broken out in India, or that plague has again appeared in China, or that influenza has made a new appearance in some European country, we do not trouble ourselves much about it. It seems to be far away, and not to concern us acutely. But it does concern us, and long before the newspaper made the announcement the matter was known to those whose business it is to defend us against the coming danger—the Public Health Department. It has its representatives in all parts of the world, and one of its chief functions is the exclusion of the communicable diseases from our country.

KEEPING THE DISEASE OUT OF THE COUNTRY.

When an epidemic disease occurs in any part of the world, our health officers keep careful watch that no cases of the disease embark for our country.

But sometimes cases of the disease break out after the vessel is at sea, either because some thought to be well at the time of embarkation were already in the incubation period of the disease, or because actual sufferers were deceitfully concealed on the ship.

Vigilant care must therefore be taken at each of our own ports to see that no ill person lands. It has been the custom for centuries to keep ships from infected ports "in quarantine," that is, at some distance from the port, until the period of incubation of the disease feared, having elapsed, no one on board is likely to have it.

Whenever an epidemic breaks out, a considerable number of people at once desire to do a very natural thing, that is, to get away from the danger by going somewhere else. Thus, there is a great increase in travel. I do not know of a better writing from which one can reach a full realization of this desire to fly from the danger than De Foe's "Journal of the Plague Year." It is worth reading. Here are some short extracts from it:

> . . . the richer sort of people, especially the nobility and gentry from the west part of the city, thronged out of town with their families and servants in a very unusual manner; and this was more particularly seen in Whitechapel; that is to say, the broad street, where I lived; indeed, nothing was to be seen but waggons and carts, with

goods, women, servants, children, etc.; coaches filled with people of the better sort, and horsemen attending them, and all hurrying away; then empty waggons and carts appeared, and spare horses with servants, who, it was apparent, were returning, or sent from the countries to fetch more people; besides innumerable numbers of men on horseback, some alone, others with servants, and, generally speaking, all loaded with baggage and fitted out for travelling as any one might see by their appearance.

This was a very terrible and melancholy thing to see, and as it was a sight which I could not but look on from morning to night, for, indeed there was nothing else of moment to be seen, it filled me with very serious thoughts of the misery that was coming upon the city, and the unhappy condition of those that would be left in it.

This hurry of the people was such that for some weeks there was no getting at the Lord Mayor's door without exceeding difficulty; there was such pressing and crowding there to get passes and certificates of health for such as travelled abroad, for without these there was no being admitted to pass through the towns upon the road, or to lodge in any inn. Now as there had none died in the city [By "the City," he refers to the present small section of London called by that name], for all this time my Lord Mayor gave certificates of health without any difficulty to all those who lived in the ninety-seven parishes.

This hurry, I say, continued for several weeks, that is to say, all of the months of May and June, and the more because it was rumored that an order of the government was to be issued out to place turnpikes and barriers on the road to prevent people travelling, and that the towns on the road would not suffer people from London to pass for fear of bringing the infection along with them, though neither of these rumors had any foundation but in the imagination, especially at first.

I know that the inhabitants of the towns adjacent to London were much blamed for cruelty to the poor people that ran from the contagion in their distress, and many very severe things were done, as may be seen from what has been said; but I cannot but say also that, where there was room for charity and assistance to the people, without apparent danger to themselves, they were willing enough to help and relieve them. But as every town were indeed judges in their own case, so the poor people who ran abroad in their extremities were often ill-used and driven back again into the town; and this caused infinite exclamations and outcries against the country towns, and made the clamor very popular.

. . . .

It is true, hundreds, yes, thousands of families fled away at this last plague, but, then, of them many fled too late, and not only died in their flight, but carried the distemper with them into the countries where they went, and infected those whom they went among for safety; which confounded the thing, and made that be a propagation of the distemper which was the best means to prevent it; and this too is an evidence of it, and brings me back to what I only hinted at before, but must speak more fully on here, namely, that men went about apparently well for many days after they had the taint of the disease in their vitals, and after their spirits were so seized that they could never escape it, and that all the while they did so they were dangerous to others; I say that this proves that so it was; for such people infected the very towns they went through, as well as the families they went among; and it was by that means that almost all the great towns in England had the distemper among them, more or less, and always they would tell you such a Londoner, or such a Londoner, brought it down.

These fugitives are a great source of danger. Charity seems to demand that they be aided in their efforts to escape the threatened evil, but good sense cautions us. Not a few of them have already been in contact with the sick, some of them may be in its incubation stage, they will fall ill on the way, and thus, wherever they go they take the very disease they are, themselves, trying to escape. As in travelling people are usually brought into closer quarters than at home, travelling soon becomes more dangerous than remaining at home. Thus those trying to escape an epidemic may not only be "jumping out of the frying pan into the fire," but may be innocent incendiaries starting new fires all along the way.

In keeping an infectious disease out of the country one must not go on the assumption that there is plenty of time. In these days of rapid transportation by great trans-oceanic liners, only a few days may elapse before an epidemic disease reported in a foreign port, is brought to our own. Cholera breaks out in Hongkong, and the very next ship may bring it into San Francisco; plague is reported in Alexandria, and in a few days it is in New York. Immigrants landing from the ship may carry it to a dozen middle western cities in the course of the next day or two.

It is necessary at all times to examine those arriving upon a ship, to see that they do not bring an infectious disease into the country. In times when no epidemic is in progress, and the vessel, well reported from the port of departure, the examination may seem to be perfunctory. To those of you who have crossed the sea it may have seemed so, but several things may have escaped your attention. You were in the cabin; during the voyage you were more or less constantly under observation. The steward, the stewardess, the officers, the ship's doctor probably knew you and that you were not ill—if you had been so you would probably have called the doctor, certainly the steward or stewardess, and would have had your meals brought to your room. When you, therefore, appear for examination it is as one already known to be well. If, however, you had been in steerage, the examination might have been so searching as to seem a trespass upon individual rights and privacy, as indeed, I have heard it declared to be.

But, you may say, why be so particular with the poor steerage passengers when it is known that the port from which they come is not infected, and when no epidemic is raging? The Public Health Service is not only interested in epidemics, it is important to keep out *all infectious diseases.* It is

not enough to keep out only the rare and dangerous ones. Every additional case of the familiar and common infectious diseases is an added source of danger, for there is always the possibility that the case so admitted may bring in a more virulent micro-organism than that to which we are accustomed.

The duty of the health official at the port of entry does not end with the passengers. It is as important to keep out the fomites as the patients. Their baggage and the cargo must be as carefully attended to and sterilized if necessary.

Within a year or two shaving brushes were admitted from a foreign country, the bristles in which having been taken from diseased animals were infected with anthrax. These brushes were the cause of a number of cases of malignant carbuncle among the soldiers in the American army. Such a misfortune could never have occurred had the danger been known and the brushes kept out, or carefully and appropriately sterilized before admitted to commerce.

It is also important to keep out infected animals to prevent epidemic diseases among animals.

A good example of success in the exclusion of disease under highly favorable circumstances, is found in the extinction of rabies or hydrophobia in the British Isles. England is an island; no man

or animal can enter except by crossing the water. If you desire to take a dog into England, you will encounter all kinds of trouble and delay. It is because though there used to be hydrophobia in England, with great perseverance it has been exterminated by killing every animal that showed symptoms of it. Having successfully accomplished that, the authorities do not intend to have any more of it. Hence if one wants a dog from another country, it is necessary to leave it in quarantine, at the port of entry, for a long time until all danger of the appearance of the disease is passed. When the authorities are fully satisfied that the animal is free from all danger, it is released.

The same system could not bring about the same happy results either in this country or on the continent of Europe. In both, civilization borders upon wild forested territories inhabited by wild animals among which rabies is endemic, and from which it is imparted to the nearby dogs that impart it to others and so on.

KEEPING THE MICRO-ORGANISMS OF INFECTIOUS DISEASES OUT OF THE HOME.

If it is a good plan to keep the micro-organismal enemy out of the country, it is no less important to keep it out of the home. But how is it to be done?

It appears in many different forms, to each of which careful attention must be devoted.

When a friend is unfortunate enough to suffer from an infectious disease, we are, of course, sorry, and desire to afford him any aid or comfort in our power. But if it be an affection that can be communicated to us or our children, the only sensible thing to do is to deny him access to our house until the danger is passed. Nor should we visit him in his house, to run the risk of bringing the infection away with us.

This may seem to be a supererogation, but it is not. When sickness comes it arouses our feelings of sympathy and makes us guilty of great folly. In some communities illness affords a social opportunity and the sick room becomes a reception hall.

KEEPING VERMIN OUT OF THE HOME.

It is a good thing to be ready for trouble when it comes and to keep one's house in order. It has already been shown that some insects can spread the micro-organisms of some infectious diseases by their bites. More about it will come later. But seeing that is true, it is well to pause a moment to consider that if there were no vermin in our houses certain of the infectious diseases could not spread there. Remember the rôle of the lice in typhus

fever, and think how important it is when typhus fever comes for everybody to be free and remain free of those insects.

If all of the people could be made to realize that vermin is a menace as well as a nuisance, they would, no doubt, gladly assist in their extermination.

Lice are easy to get rid of, any doctor, nurse or druggist can tell you how to do it.

KEEPING MOSQUITOES OUT OF THE HOUSE.

Mosquitoes being insects less intimate than those just mentioned, are tolerated with equanimity by many who would shudder at the thought of lice. They are, however, a pest, disturb sleep, and are agents for the transmission of the micro-organisms of yellow fever, dengue fever and malarial fever. They, and all other biting insects, should be carefully excluded from every house, especially in districts in which the diseases mentioned prevail or are possible.

KEEPING FLIES OUT OF THE HOUSE.

It is difficult to understand how, in times when the newspapers have had so much to say about the filthy but festive house-fly, anybody can any longer tolerate its presence in his house. It is true that it is not known to be a regular vector of any disease,

but its filthy habits make it the possible vector of many. The chief danger is from its disgusting habit of first frequenting the privy, and then at the ringing of the dinner-bell, coming to the table without taking the trouble to wipe its feet.

It comes soiled with all the micro-organisms that have been picked up in the course of its peregrina-

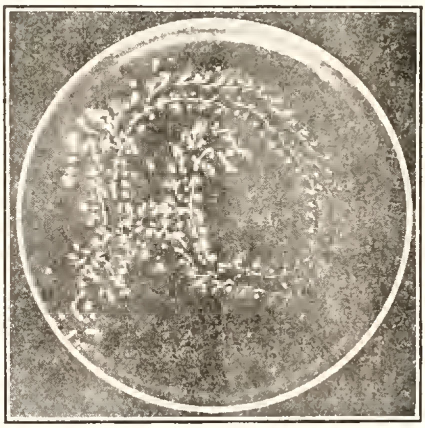


Fig. 12.—Petri dish infected by a fly. In the bottom of the dish there is spread a thin layer of sterile culture jelly. Upon it the fly was permitted to walk, then the dish was closed and stood away. At each point touched by the fly's feet, colonies of bacteria developed. (*Coplin.*)

tions, among which there may be nothing harmful, or among which there may be those intestinal bacteria of pathogenic nature about which mention has already been made—typhoid fever, paratyphoid fever, cholera (during epidemics), or dysentery. These it does not hesitate to scatter over the sponge cake and preserves which strongly attract it, and

thus it may happen that with our dessert we unexpectedly swallow a dose of poison.

No one should expose articles of food in such a manner that flies can soil them; no one should purchase foods so exposed; no one should tolerate flies in his kitchen or dining-room.

WATER.

But certain things must at all times be admitted to the house, and one of them is water. Small quantities of it are indispensable; larger quantities a delight and a luxury, and one of the great advantages enjoyed by the American people lies in the greater per capita quantity they are allowed, as compared with most others.

But water must be pure or it is apt to be as much of a curse as a blessing. Certain diseases, because of the frequency with which their micro-organisms are contained in water, receive the name "water borne." They are typhoid fever, paratyphoid fever, cholera, and dysentery, the micro-organisms of which, present in human excrement are carelessly or accidentally permitted to enter the wells or other sources of water supply.

It might be supposed that as soon as this fact became known, people would clamor for pure water only. But the human mind is sometimes slow to act,

and fear of increased expense sometimes "makes us rather bear those ills we have than fly to others that we know not of."

Long years after the large cities of the world had learned about water-borne diseases, and were providing their people with pure, filtered or chemically treated water, the city of Philadelphia calmly continued to supply its citizens with raw sewage from the Delaware and Schuylkill rivers, killing many of them annually from typhoid fever that was entirely preventable. It was only after prolonged delay that filtration plants were built, and reasonably pure water—in the sense of purified water—was at last available. Almost immediately typhoid fever that had been one of the most common diseases in Philadelphia became one of the rarest. This was a glorious achievement, and one of which its citizens ought to be proud, although it had been so long deferred that hundreds of them died before it was accomplished. But there remains a circumstance of which they ought to be ashamed and that ought to fill them with anxiety. The quantity of this purified water scarcely meets the requirements of daily consumption and every time an accident occurs in the water system it is at once necessary to supplement the supply by "raw pumpage," which contains the same sewage poisons that the people used to get.

One can usually tell when such accidents have occurred by the recommendation made in the newspapers, and sometimes by circulars distributed by the Board of Health, that the *water be boiled*. Is it not the duty of every citizen to familiarize himself with this condition and to assist in demanding that

Fig. 13.—Bacillus typhosus. × 1000.

The tiny bacillus swims about actively, propelling itself by means of a number of long flexible cilia that give each organism a spider-like appearance in this preparation that has been stained by a complicated process specially devised to show them.

additions to the pumping and filtering plants be made, and new and commodious reservoirs for reserve supplies of filtered water be erected? Of course it is. Whose turn will it be to get ill next time? Almost every time it happens somebody gets ill, and not infrequently dies.

BOILING THE WATER TO MAKE IT PURE.

The purpose of boiling water is to kill any disease producing micro-organisms that it may contain, and it is an efficient method of destroying them, but it is also a snare and delusion because of the difficulty of carrying it out consistently.

It may help to boil the drinking water, but that is not enough.

What about the water used for scrubbing the teeth? What about that used for culinary purposes? How about that used for bathing? How about that used in the kitchen for washing celery, lettuce or fruits? Do you not see that boiling the drinking water is not in itself sufficient if the water be really dangerous? Boiling it is also expensive and troublesome, and therefore very likely to be neglected by the economical or careless, and requires large pots and containers that most people do not have. It is only a makeshift, and never should be necessary. Unless an adequate supply of pure water is available for every citizen, a city is not doing its duty.

MILK.

Milk is the chief source of nourishment for infants and sick adults, both of which classes of individuals are particularly susceptible to infectious

disease because of their enfeebled condition and general lack of resistance. If, therefore, the milk be bad they are likely to suffer.

Milk may be bad in several ways: first, it may be taken from diseased animals from whose blood as in the case of goats infected with Malta or Mediterranean fever, or diseased udders as in the case of tuberculous cows, micro-organisms enter it; second, it may be spoiled—soured—through the entrance from the air, or containers, of contaminating micro-organisms, not in themselves really dangerous, but capable of conferring poisonous properties upon it as it sours; third, it may be infected by the micro-organisms of the water-borne diseases, cholera, typhoid, paratyphoid or dysentery, added intentionally for the purpose of dilution, or accidentally in washing the cans; lastly it may be infected with the micro-organisms of diphtheria, scarlet fever or typhoid fever, by carriers of those diseases.

Is it any wonder that health authorities everywhere engage in earnest campaigns for good milk? The results are very gratifying.

Tuberculous cows are, in many states, being sought out by the authorities, bought, and killed; so that the danger from bovine tuberculosis, once common, is being greatly reduced. The dilution of milk for the purpose of increasing its volume, which

is illegal, meets with swift punishment, and has become almost a thing of the past.

The proper cooling and pasteurization of the milk at the dairy, and its distribution in bottles is doing away with the danger of injurious souring; and the repeated bacteriological examinations required before those known to have suffered from infectious diseases are given liberty, is eliminating the danger of infection by "carriers" of infection. But unfortunately these improvements apply chiefly to the milk consumed by the better classes. Go among the poorer people and see where their milk comes from, how it is served, how it is kept, who handles it, and how, and you may find that every one of these important considerations is neglected by those too ignorant to understand them, or too avaricious to practice them.

So it comes about that the very class of people who most need protection, and for whom the sanitary rules and regulations are made, fail to derive the expected benefit.

OTHER FOODS.

From the standpoint of micro-organismal infection and the occurrence of epidemic disease the other foods usually play a subordinate rôle. However, it must be pointed out that in districts where

human excrement is used to fertilize the soil, and intestinal infections abound, the greatest care must be exerted to eliminate the dangers that may lurk in the green vegetables. Fruits that grow upon trees, and berries from bushes may be harmless, but whatever comes from the ground, or has been carelessly sprinkled with water from such soil, should not be eaten until thoroughly cooked. In the Orient where contamination of the soil and water are almost universal, and the ignorant carelessness of the nations proverbial, exemption from cholera during an epidemic is only to be purchased through eternal vigilance and the practice of scientific precautions.

KEEPING THE INFECTIOUS AGENTS IN—SEGREGATION OF THE SICK.

My grandfather told me that, when he was a boy, it was not unusual to see children with the smallpox eruptions upon their faces, playing on the front door steps of their homes. In those days everybody expected that he would sooner or later get the disease, and considered himself lucky if he escaped.

If patients suffering from transmissible diseases were in no way restricted in their movements, many of them would go walking about the streets and visiting their friends with the inevitable result that there would be a great increase in the number of

cases of the diseases from which they were suffering. Fortunately they are now kept at home, and a notice attached to the door informs a visitor that danger is within!

Who would today answer his front door bell if he suspected that the visitor might have small-pox? And yet, being vaccinated, we need not greatly fear the disease. What we fear and ought to fear, is that we may not be well enough or recently enough vaccinated to be perfectly safe. Persons suffering from transmissible disease ought not to be at large, and ought not subject others to the danger of infection. We have had measles, and do not usually take it again, but we may, and therefore it is not wise to expose ourselves to measles unnecessarily. The same is true of all other infections.

To make the city safe it is not only advisable, but essential to forbid any person with an infectious disease in a communicable stage to be at large. In the present state of society there may have to be exceptions. Tuberculosis, for example, is so prevalent that it does not seem practicable to segregate the cases; but the principle is the correct one, and the time may come when more stringent regulations with regard to it will be enacted. But we are not discussing chronic and universal diseases like tuberculosis just now. We are chiefly concerned

with infectious diseases that are likely to become acutely epidemic—diphtheria, scarlatina, measles, chicken-pox, small-pox, and so on.

A patient suffering from any of them, as well as those caring for him, must be kept at home, lest the disease be carried to others. If for any reason it is not practicable to keep him in his home, he should be removed to a hospital where he can be properly treated and cared for.

I doubt whether there are many who cannot see the importance of this and do not approve of it. Yet when illness comes, and the infectious disease is in their houses, many take umbrage at the restrictions, think that since misfortune has come upon them, and necessity compels them to take the risk of infection as they minister to the sick, others may look out for themselves. It is, therefore, often necessary to take extreme measures and have guards stationed at the entrances of the house to compel the occupants to stay in. It does seem harsh, but it is necessary.

KEEPING THE ILL IN ASYLUMS AND HOMES.

A number of the infectious diseases are of long duration, incapacitating, and therefore impoverishing. Among these are tuberculosis, leprosy and syphilis. Patients suffering from them should be

afforded an opportunity to retire for treatment into asylums or homes where the danger of infecting others would not exist, and from which they might again enter society as they recovered or entered upon an inactive and therefore not transmissible stage of the malady.

CARE OF CASES OF VENEREAL DISEASE.

Venereal diseases constitute another class of cases of great public interest. They comprise gonorrhea, chancroid and syphilis: three important, dangerous and much neglected diseases. They are highly transmissible as is evidenced by their great prevalence, though they are as a rule but slightly incapacitating. The usual result is, that the sufferers go about as usual, and not infrequently spread the contagion. If they are really ill as sometimes happens, and desire to retire for treatment as they should, few hospitals will take them, and public sentiment seems to be opposed to rendering them assistance, apparently on the ground that they have but received the "wages of sin," and are being justly punished. Nothing is more false or ridiculous! The men or women suffering from a venereal disease differ from others only in being less fortunate. They need assistance in the worst way, not only for their own good, but for that of the public as well.

In many cases they fall victims to the most unscrupulous of quacks, who bleed them of their money, do them little or no good, and keep them in the midst of society without giving sufficient information to prevent them from becoming distributors of the germs of the disease from which they suffer, and of which after recovery they are almost certain to remain for a long time carriers.

SEARCHING FOR THE CARRIERS OF DISEASE.

This is a difficult problem for the sanitarian. How shall the well persons who carry in their bodies the agents of infection be found? Until recently their number and importance were not realized; no effort was made to find them, and so numbers of them are abroad.

It was through the bacteriological study of diphtheria that the matter really began, for it was soon found that living and virulent bacilli remain in the throat a long time after recovery, and that it was inexpedient to permit a patient to return to school or society until he ceased to be a carrier. Examinations of the throat had to be made every week, and sometimes the bacilli did not disappear for months. Later bacteriological examinations of the throats of those attending diphtheria cases, or coming into contact with them, showed them also to harbor the bac-

illi; and it became necessary to treat them in the same manner as the convalescents.

If the entire population could be carefully examined and all the patients as well as all of the carriers of infectious diseases segregated until they could no longer transmit the micro-organisms, it would not be long before it would be much the same condition as Camp Beauregard, to which reference was made upon an earlier page. When all of the patients were in the hospital, and all of the carriers in the detention camp, there ceased to be any new cases of cerebrospinal meningitis. But that is impossible at present. All that can be done is to attempt to educate the public to desire the cure of such diseases as they have, to desire not to spread them, and to follow such advice as they receive from their personal medical advisors and the sanitary authorities.

While I was a medical officer in the United States Army during the recent world war, a small epidemic of diphtheria broke out in one of the hospitals at which I was stationed. It was a comparatively easy thing to bring it to a close, but in the course of the routine examinations, it was found that two of the younger medical officers were carriers of the micro-organisms.

Realizing the gravity of the situation, they accepted the required restrictions, and when in the

post went about with their faces covered with masks of antiseptic gauze. They engaged in no medical work, ate at a separate mess table, associated only with one another, kept from all places of amusement, and avoided gatherings and crowds.

At first it was a kind of joke, and they made a holiday of it.

But as the days wore into weeks, and the weeks bade fair to lengthen into months, their courage began to fail. Fortunately about that time the repeated examinations showed no more diphtheria bacilli in their throats, and they were liberated.

But suppose that had not happened, suppose they had continued to harbor micro-organisms. What then? Well, as they were in the army, perhaps continuation of the segregation and precaution could have been insisted upon. But how long? For years? For life? It is a very important problem as is shown by a famous case.

TYPHOID MARY.

Every now and then one reads in the newspaper about a typhoid carrier—"Typhoid Mary." She has been known and her movements followed for years, and she seems doomed to be and remain a carrier for life. Her occupation is domestic service, and so far as I know she may be an excellent ser-

vant. But in every home in which she lived there sooner or later appeared a case of typhoid fever, always traceable to her. What should be done about it? If you were an authority what would you do?

Let her go on living at service and giving people typhoid fever? Would you let her live in your own family? In the family of any of your friends?

But on the other hand if you were Mary, how would you look upon the restriction of your liberties? If you were her father or brother how would you feel about it?

Poor Mary! After being in trouble more or less all the time for years, she seems to have given up the fight. In the last mention I saw about her it was said that she had consented to accept a home for life in an institution.

But is it not true that when such a carrier is found, public safety is only to be maintained through her isolation? Is not the safety of all more important than the freedom of one?

THE PREVENTION OF DISEASE THROUGH THE INCREASE OF THE RESISTING POWER.

When a living creature is able to defend its body from invasion by micro-organisms it is said to be *immune.*

From the technical point of view immunity is a very complicated and difficult subject to understand; from the practical point of view it is very simple. Any one can understand its fundamental principles and the rationale of its practical workings.

Every infection is a conflict between a *micro-organism infecting* (*parasitic*) and an *organism infected* (*host*).

THE INFECTING ORGANISM.

We have already seen that micro-organisms are divisible into two classes, the *harmless* and the *harmful.* When members of the first class enter the body they are so promptly destroyed and eliminated that no visible signs of their presence can be detected. But when members of the second class arrive, more or less damage is effected, varying from slight local inflammatory disturbance to general invasion of the body followed by death.

Previously it was shown that all human beings are not exactly alike, but that slight chemical and other differences obtained among them. It is the same with the micro-organisms. If a pure culture of almost any micro-organism be so distributed as to permit its individuals to be separately studied, differences will usually be found among them. Some differ in the rapidity with which they grow, and so may be said to excel in vegetative activity. Others in the production of a pigment, in the evolution of a gas, in the evolution of an odor, or in the ability to invade the bodies of certain animals. These differences are not great, but they are differences, and have their effects in the results that follow the introduction of the particular micro-organisms into animals, and in the morbid conditions that will follow, because they determine how the animal will react.

Let me try to make this clear by an example: Roses are not all alike. Even on the same bush they are not all alike. Some roses are red, some pink, some white; some grow in abundance, some have but a few flowers on a bush; some are large, some small; some have a sweet perfume, some none at all; some have no thorns, others so many that it is almost impossible to handle them. These are all small differences among roses, but they may be of a

character to determine our reaction to the flowers. Suppose we set out to pick a bouquet. We have no knife or scissors, so we will not touch those with numerous thorns; we have a fondness for red, so we choose only the red flowers, and let the others remain; we desire only the largest, so we touch none of the small ones, and so on. If we happen to be provided with gloves, knife or scissors, the whole proceeding may be modified, and only the thorny ones may be selected because they particularly attract us on account of their size, color and other excellences.

In the unconscious treatment of infecting micro-organisms in the infected body, the defending cells show comparable reactions to the differences in the micro-organisms. If they are attractive to them they may attack and destroy; if unattractive they may leave them untouched to go on and invade.

THE INFECTED ANIMAL.

The differences between persons are comparable in the results to which they lead, and are sufficient to account for many of the irregularities of infection.

That one may have virulent diphtheria bacilli in the throat, yet not have diphtheria is thought a curious phenomenon by many who see nothing peculiar in the fact that of those that do have the disease

some die, and others get well. Why do not all die or all get well? The latter is as difficult to explain as the former, but it does not seem so because one is acquainted with the latter fact and knows from experience that it is true, but the former fact is a new one outside of individual experience.

It has already been pointed out that differences in the chemical condition of some individuals, and the natural presence in the blood of a substance that can interfere with the action of the diphtheria bacillus and neutralize its toxin, explain that some cannot get the disease that so readily attacks and even kills others. Similar differences account for the fact that some die and others get well.

There are very few micro-organisms so destructive in their effects, and equally few individuals so susceptible, that all infected must die. The majority of those infected get well from the greater number of diseases. This shows that the greater number of individuals have a certain amount of resisting power. How fortunate it would be if there were some way of increasing their resisting power, and making them all equally inimical to the invasion of micro-organisms!

Nature seems to endeavor to assist us in this particular, but her methods are haphazard and too lacking in uniformity to be depended upon.

Her method seems to be to assist only those already able to help themselves, and let the others die.

A SECOND ATTACK OF AN INFECTIOUS DISEASE IS RARE.

The general prevalence of infectious disease is such that few individuals escape chicken-pox, measles, mumps, scarlatina, and whooping-cough in childhood. Indeed, they are collectively known as "diseases of childhood."

With regard to them it is common knowledge that having once had them, in some way prevents another attack. It is also a wide-spread belief that if having them is postponed until adult life, they seem to occur with exceptional severity.

The result is that many parents and a few physicians believe that it may be best to have them in childhood and so be done with the whole business. They therefore take no precautions to avoid exposing their children, but let them play together and get the infection from one another.

This is bad practice in all cases, but it is criminal practice with respect to scarlatina, measles, and whooping-cough, any of which may terminate fatally.

After having recovered from any one of these diseases there is little danger of getting it again.

Having it, therefore, changes one in some particular—he has become immune. It is Nature's way of defending.

But if the diseases against which the defence was sought be small-pox, yellow fever or plague, all of which are very dangerous and fatal, and the first of which is very disfiguring, is it not a very expensive method?

It might not be if it were possible to so arrange matters that the disease could be lived through without injury.

THE MITIGATION OF SMALL-POX BY THE METHOD OF INOCULATION.

I do not think it has been determined how or when they arrived at the idea, but Asiatics, especially the Chinese and the Turks, have for centuries practiced a method by which they induce mild attacks of small-pox for the purpose of preventing subsequent severe and perhaps fatal ones. When Lord Montague was made the British ambassador to Turkey, he took his wife with him, and it was through her influence that the method of "ingrafting" or "inoculation" was introduced into Europe. Here is what she said about it in a letter to Mrs. Sarah Chiswell, dated Adrianople, April 1st, O.S. 1717:

Apropos of distempers, I am going to tell you a thing that I am sure will make you wish yourself here. The small-pox, so fatal and so general among us, is here entirely harmless by the invention of *ingrafting*, which is the term they give it. There is a set of old women who make it their business to perform the operation every autumn, in the month of

Fig. 14.—Lady Mary Wortley Montague.
She introduced into England, from Turkey, the method of "inoculation against small-pox."

September, when the great heat is abated. People send to one another to know if any of their family has a mind to have the small-pox; they make parties for this purpose, and when they are met (commonly fifteen or sixteen together), the old woman comes with a nut-shell full of the matter of the best sort of small-pox, and asks what veins you please to have opened. She immediately rips open that vein

you offer to her with a large needle (which gives no more pain than a common scratch) and puts into the vein as much venom as can lie upon the head of her needle, and after binds up the little wound with a hollow bit of shell: and in this manner opens four or five veins.

The Grecians have commonly the superstition of opening one in the middle of the forehead, in each arm and on the breast, to mark the sign of the cross; but this has a very ill effect, all these wounds leaving little scars, and is not done by those that are not superstitious, who choose to have them in the legs, or that part of the arm that is concealed. The children or young patients play together all the rest of the day, and are in perfect health till the eighth. Then the fever begins to seize them, and they keep their beds for two days, very seldom three. They have very rarely above twenty or thirty in their faces, which never mark; and in eight days time they are as well as before their illness. Where they are wounded, there remain running sores during the distemper, which I don't doubt is a great relief to it.

Every year thousands undergo the operation; and the French embassador says pleasantly that they take the small-pox here by way of diversion, as they take the waters in other countries. There is no example of anyone that has died in it; and you may believe I am very well satisfied of the safety of this experiment, since I intend to try it on my dear little son.

Introduced into England, this method became fashionable and was helpful for a time. It was based upon sound scientific principles. These were, that small-pox is usually less dangerous when endemic than when epidemic, and that one is best able to successfully combat an infectious disease when

in the best of health. But there were decided objections to it. The disease conferred by the operation was small-pox, was therefore contagious, and might prove fatal. It was widely and rightly practiced until a better method of preventing the disease was discovered.

PREVENTION OF SMALL-POX BY VACCINATION.

But a little later, in Europe, observation, supported by the growing tendency to experiment, was preparing the way for a more safe means of preventing small-pox. It was known in many places that milk-maids and others in frequent contact with cattle, occasionally acquired a disease, characterized by pustules on the hands, and sometimes on other parts of the body, and known as cow-pox. It was also common belief that those having had this accident, did not take small-pox. Does it not now occur to everyone that if protection from a dreadful, disfiguring and frequently fatal affection such as small-pox, could be guaranteed through an attack of cow-pox, it might be well to investigate and see whether it were so? The thought is said to have occurred to Nicholas Plett, a school-master of Starkendorf, in Germany, in 1791, and he tried it upon three school-children. What the final results were history does not say, as the parents of the children,

furious at what they regarded as a sinister purpose on the part of Plett, drove him from the town.

Exactly the same thought, with the same experimental trial was made in England, some time about 1774, evidence of it being found upon an old tombstone that still stands in the grave-yard of the old Dorset church of Worth Matravers, among the Purlock Hills. It says:

> Sacred to the Memory of
> Benj. Jetsy (of Downshay)
> Who departed this life April 16th, 1816
> aged 79 years.
>
> He was born at Yetminster, in this county & was an upright & honest man: particularly noted for having been the first person (known) that introduced Cow-Pox by inoculation, & who from his great strength of mind made the experiment from the cow on his wife & two sons in the year 1774.

It was in the early spring of 1796 that Dr. Edward Jenner visited the country house of a friend. In the dairy he fell into conversation with a milk maid, the beauty of whose complexion astonished him. "How sad it would be," said the gallant doctor, "if the small-pox should ruin this pretty face of yours." "Oh, but it cannot," answered the maid, "because I have had cow-pox."

This led Jenner to think and inquire about the matter, and finally to experiment. His first at-

tempt was made on May 14, 1796, when, with matter from a pustule of cow-pox on the arm of a milk maid, Sarah Nelmess, he infected the arm of a little boy named John Phipps. After the lad had recovered from the cow-pox, Jenner inoculated him with

Fig. 15.—Edward Jenner.

An English practitioner of medicine who first succeeded in demonstrating and popularizing the prevention of small-pox by vaccination.

small-pox, but found him insusceptible to the disease. That experiment was the beginning of *vaccination*, the preventive method that has been the saving of millions of human lives, and has made small-pox almost disappear from civilized countries.

The advantage of *vaccination* over *inoculation* is immense for it occasions a disease that is not contagious and not disfiguring, and not fatal.

Now if small-pox does something to its victims that prevents another attack, and if the result of the operation of ingrafting, or as we know it inoculation is a mild attack that confers the same benefit, we see in vaccination a safe and sure short cut to the same benefit.

It is frequently asked, "What is the vaccine virus; what is its relation to the small-pox?" I think that I express the generally accepted view today held among scientific men, when I say that it is probably small-pox virus, changed in some manner, by having lived in the cow. The cow is not susceptible to small-pox as we ordinarily see it, but that does not mean that the micro-organisms of small-pox cannot live in the cow at all. It is a very common thing for micro-organisms to produce entirely different appearing conditions in different animals. It is not so common for them to be thus modified in effect upon one kind of animal by having lived in some other kind. About the change, or the manner in which it is affected, speculation is worse than useless, as we are not sure what kind of an organism causes small-pox. We know it by its effects not by its appearance.

But all this is idle speculation. We know that the effect of vaccination is some kind of increase in the body defences by which we successfully resist future invasions by both the cow-pox and by the small-pox micro-organisms.

THE RESULT OF A BATTLE WITH THE MICRO-ORGANISMS.

What we are now most interested to know is how having a disease, being inoculated (which is really the same thing), or being vaccinated gives protection.

It is through an increase in the resisting powers. To be able to live through the first attack showed a certain amount of resisting power; we were compelled to suffer for a time as the hostile micro-organisms invaded us, but we were able to increase and gather our defensive forces until we came out victors in the end. The gathered defensive forces are the secret of it. We may not be able to assert in precise scientific language or in definite terms of chemistry just what they are, but that does not matter. In the war through which we have just passed we made great quantities of munitions—guns, explosives, shells, poisonous gases, etc. The war is over, but we still have them, and does anyone suppose that we are not more powerful because we have

them, and will not continue to remain more powerful because of them, than we were before we had them in 1914? Not only that but we have left over four millions of trained fighting men (which may be taken to represent the white blood corpuscles which are the fighting cells by which we catch and destroy micro-organisms) that we did not have before. After we have carried on a successful warfare with micro-organismal foes it is the same. We are left in possession of trained and experienced fighting cells, and quantities of immunity products with which to discourage and extinguish future attacks from similar foes.

TO WIN THE PROTECTION IT IS NECESSARY TO SUFFER.

Vaccination is so trifling a matter compared to small-pox that it has become the custom to speak of it as though it was only an operation and was not a disease. Some complain that it makes them ill, others are horrified to learn that *the purpose of it is to make them ill.* But let there be no mistake about it; it is to produce an illness that the operation is performed, and without that it is of no benefit and had better not be done. If any general statement upon the subject is possible it is that the more severely one suffers from the vaccinia, the

greater will be his protection against small-pox. Here is found an explanation of one of the matters that worry some who think a good deal about vaccination, but do not really understand it. Why do the doctors talk about *efficient* and *inefficient vaccination.* Is not vaccination vaccination? Are these terms not employed to deceive?

No; vaccination is only an operation. It is performed for the purpose of causing vaccinia and can be efficient only when it is followed by an attack of that well recognized disease. The idea that vaccination is an operation and that having had it performed one is saved from further trouble, as, for example one is saved from further attacks of appendicitis through having his appendix cut out, is entirely false. The operation is only the means of infection. It may lead to nothing, as, for example, if the virus used, having been kept too long, should contain only dead micro-organisms, or if through misapplied effort to prevent accident, the virus was killed at the time of introduction through the application of germicides intended to prevent complicating infection. If for these or any other reasons the vaccination does not "take," which means be followed by no attack of disease, it should be done again. It may, indeed, be necessary to do it several times before the desired end is achieved.

As it is true of other infectious diseases there are a certain number of persons that will not "take." They are naturally insusceptible to the disease. It is probably true that in most cases they are also insusceptible to small-pox, but that does not necessarily follow. Then there are a few that do "take" but derive no benefit. How to explain these very rare cases we do not know, but that is no matter. They are only the exceptions to the general rule, and are too few to be more than curiosities. That which we do know, and which is of the greatest interest is that in nearly all cases vaccination does take, and does protect from small-pox.

OTHER KINDS OF VACCINATION.

If living under the different conditions in the body of a cow, can change small-pox micro-organisms so that they lose their dangerous qualities while retaining their immunizing powers, can the same or some similar treatment modify other viruses in the same way? Yes.

I wish that every reader of this book would also read "The Life of Pasteur" by Vallery-Radot. Aside from many interesting and illuminating things, you will there find an interesting account of the observations and experiments that led to the

discovery that the preparation of vaccines for diseases other than small-pox was possible.

OBSERVATIONS UPON CHICKEN-CHOLERA.

This is how the first observation was made. In 1880 Pasteur was engaged in the study of a certain small bacillus found to be the cause of a very fatal disease of fowls known as "chicken-cholera." For a time his attention was diverted, and when he returned to take up the study again, he was disappointed to find that his cultures would no longer kill chickens. To continue the experiments it was, therefore, necessary to get new cultures. With these he reinoculated the fowls that had survived and some new ones, when to his surprise he found that the old fowls all lived, but the new ones all died. The only difference between them was that the former had received two inoculations, the latter only one. But the first inoculation had done nothing; it had failed to kill. But it was found to be entirely wrong to suppose that because they had not killed the chickens the introduced bacilli had done nothing, and that Pasteur was sufficiently sagacious to see. Pasteur could not then say to himself as you now can: "Oh, yes; the chickens were made to suffer a little, and recovered by accumulating defensive substances, so that afterwards they were immune." But he

worked it out in the end, and as the result of what at first seemed to be a misfortune, was able to devise a vaccine with which to immunize and save all the barn-yard fowls that were threatened with the disease.

Fig. 16.—Bacillus of chicken-cholera, from the heart's blood of a pigeon. × 1000. (*Fränkel* and *Pfeiffer.*)

The tiny dots are the micro-organisms, the large dark bodies the pigeon's blood corpuscles.

But, you are thinking, those bacilli of chicken cholera were not put into cows or otherwise treated, how did they become harmless? It was shown that the particular micro-organism is so sensitive to un-

natural conditions that it spontaneously loses its disease-producing power when kept in artificial culture beyond a certain length of time. In the case of the small-pox virus, life in the cow produced the diminution of virulence and modified the effect it produced in man; in the case of the virus of chicken cholera, merely keeping the virus under unnatural conditions accomplished the same end.

OBSERVATIONS UPON ANTHRAX.

There is probably no other micro-organism however, that behaves in just the same way and Pasteur found out how they differ when later he endeavored to apply the principle in the preparation of a vaccine that might be of use in protecting cattle from a disease known as *Anthrax* or *splenic fever*.

The large bacillus—*Bacillus anthracis*—that causes this disease, is a rapid spore former, and when Pasteur attempted to modify its virulence or disease producing power, he found that it always developed spores from which came bacilli as strongly pathogenic as their forebears. It was a difficult problem, but a giant intellect with infinite patience was at work. After many fruitless attempts he discovered that if the bacilli were cultivated at unusually high temperatures they ceased to go into the

spore-stage, later lost the power of forming spores, and could then be modified and afterward retained their diminished virulence.

To accomplish the successful protective vaccination of the cattle or sheep he found it necessary to give three treatments—*i.e.*, three doses of bacilli of varying degrees of virulence—first, a dose of bacilli so diminished in virulence as to be able to kill nothing larger than a mouse, then one that would kill nothing larger than a guinea-pig, and finally one that would kill rabbits. After this, the cattle or sheep were found able to successfully endure inoculation of bacilli taken directly from the blood of animals just dead of the disease.

When these results were published, a great skepticism was aroused, and not a little opposition expressed. So it was decided to give a public demonstration. Pasteur was to prepare 25 sheep by vaccination, and on a certain day 25 new sheep were to be added to them. All of the animals were then to be inoculated with virus freshly obtained from a dead animal, in the presence of a crowd of people, and the outcome noted. The public demonstration was given at Pouilly le Fort on May 5th, 1882, and the final results adjudged on June 2d. When the crowds came together on the latter date, it was found that 22 of the unprotected sheep were already

dead, two others dying, and the remaining one ill, while of those inoculated by Pasteur every one was in full health, and remained so. This was the begin-

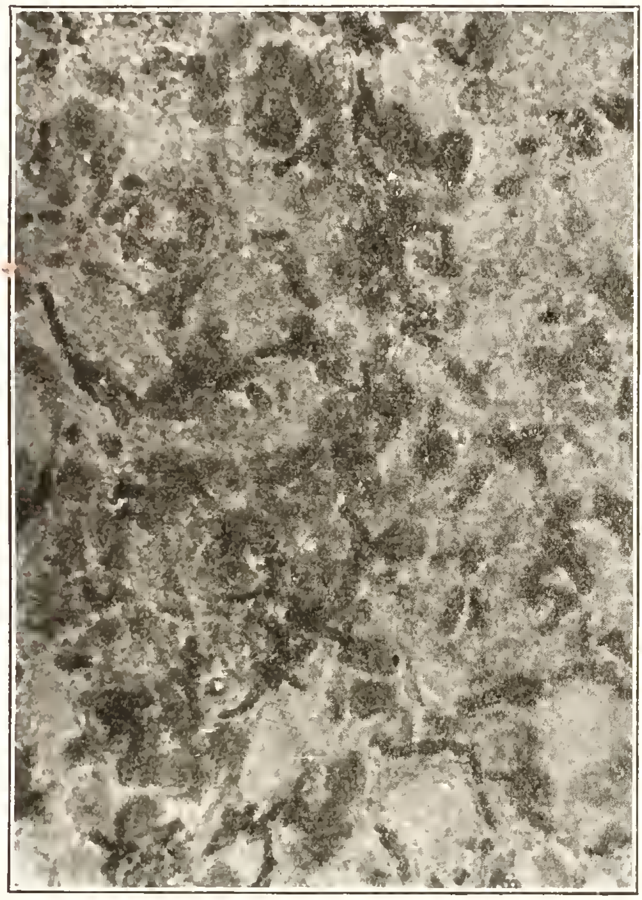


Fig. 17.—Bacillus of anthrax in the blood of the rabbit. The thick dark rods are the bacilli.

ning of a system of preventive vaccination against anthrax that is now used in all parts of the world with the saving of millions of dollars every year to the agriculturists. For it M. Pasteur was awarded

the Grand Cordon of the Legion of Honor, by the French Government.

OBSERVATIONS UPON RABIES.

Pasteur later turned his attention to a disease of man, rabies or hydrophobia. It was a source of concern to him that people should be bitten by rabid dogs, and then die from a terrible convulsive disease for which there was no remedy. The specific microorganism of the disease was not known, but that there was one was easily demonstrated, and before long he had found it localized in great numbers in the brain and spinal cords of experimentally infected animals. The thought in his mind, as the great scientist set to work, was that by the aid of some such vaccine as had proved able to protect against the other diseases, it might be possible to bring about immunity or increased resistance during the long incubation period of the disease. It is a long story, but after various trials, he found that the virus seemed to lose its virulence when dried. By drying the spinal cords of infected rabbits for varying lengths of time, and using them for injection beneath the skin, in the form of a thin paste, he was at last able to produce immunity in animals. But Pasteur was not a doctor and as it was a human disease that he sought to prevent, he was very loath to put it to

the test, lest he should do more harm than good. However, an unexpected opportunity arose.

A little boy, Joseph Meister, on his way to school was attacked, knocked down and terribly bitten by

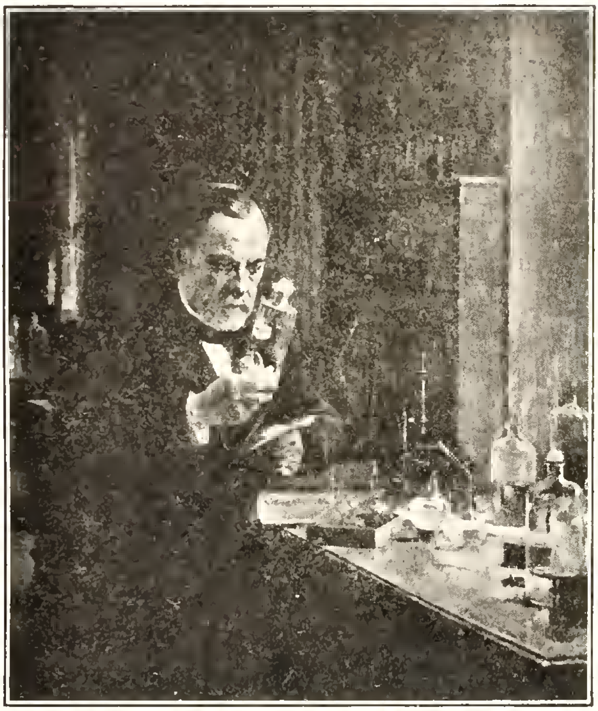


Fig. 18.—Louis Pasteur in his laboratory.
From the portrait by *Edelfelt.*

a large rabid dog. As many of his injuries were upon the head and face, it was almost certain that the child must die.

With reluctance, and only at the urgent request of his friends, Pasteur at last consented to have the new method tried. It was, and with success, for

Joseph Meister lived. Later it was tried, nearly always with success, upon a great many others, and it is today, the only means of preventing a disease of such fatality that it is doubtful whether a single case is known to have recovered without that treatment.

As I have frequently heard this first inoculation for rabies spoken of, by those unfamiliar with the details, in such manner as to make it appear as though the cruel scientist, eager only to experiment, and carelessly inattentive to the feelings of the patient, had forced it upon the helpless little patient, I take pleasure in here quoting what Pasteur's own son-in-law (Vallery-Radot) said about it:

On Monday, July 6 [1885], Pasteur saw a little Alsatian boy, Joseph Meister, enter his laboratory, accompanied by his mother. He was only 9 years old, and had been bitten two days before by a mad dog at Meissengott, near Schlestadt. The child, going alone to school, by a little by-road, had been attacked by a furious dog and thrown to the ground. Too small to defend himself, he had only thought of covering his face with his hands. A brick-layer, seeing the scene from a distance, arrived, and succeeded in beating off the dog with an iron bar; he picked up the boy, covered with blood and saliva. The dog went back to his master, Theodore Vone, a grocer of Meissengott, whom he bit on the arm. Vone siezed a gun and shot the animal, whose stomach was found full of hay, straw, pieces of wood, etc. When little Meister's parents heard all of these details they went, full of anxiety, to consult Dr. Weber, at Lille, the same evening. After cauterizing the wounds with carbolic,

Dr. Weber advised Mme. Meister to start for Paris, where she could relate the facts to one not a physician, but who would be the best judge of what could be done in such a serious case.

Theodore Vone, anxious on his own and the child's account, decided to come also.

Pasteur reassured him: his clothes had wiped off the dog's saliva, and his shirt sleeve was intact. He might safely go back to Alsace, and he promptly did so.

Pasteur's emotion was great at the sight of the fourteen wounds of the little boy, who suffered so much that he could hardly walk. What should he do for this child? Could he risk the preventive treatment which had been constantly successful on dogs? Pasteur was divided between his hopes and his scruples, painful in their acuteness. Before deciding on a course of action, he made arrangements for the comfort of this poor woman and her child alone in Paris, and gave them an appointment for 5 o'clock, after the Institute meeting. He did not wish to attempt anything without having seen Vulpian and talked it over with him. Since the Rabies Commission had been constituted, Pasteur had formed a growing esteem for the great judgment of Vulpian, who in his lectures on the general and comparative physiology of the nervous system, had already mentioned the profit to human clinics to be drawn from experimenting on animals.

Vulpian expressed the opinion that Pasteur's experiments on dogs were sufficiently conclusive to authorize him to foresee the same success in human pathology.

"Why not try this treatment?" added the professor, usually so reserved. Was there any other efficacious treatment for hydrophobia? If at least the cauterizations had been made with a hot iron! But what was the good of carbolic acid twelve hours after the accident? If the almost certain danger which threatened the boy were weighed against the chances of snatching him from death, Pasteur would

see that it was more than a right, that it was a duty to apply the antirabic inoculation to little Meister. This was also the opinion of M. Grancher, whom Pasteur consulted. Vulpian and Grancher examined little Meister in the evening, and, seeing the number of bites, some of which, on one hand especially, were very deep, they decided on performing the first operation immediately; the substance chosen was fourteen days old and had quite lost its virulence; it was to be followed by further inoculations gradually increasing in strength.

It was a very slight operation, a mere injection in the side (by means of a Pavaz—hypodermic—syringe) of a few drops of a liquid prepared with some fragments of medulla oblongata. The child who cried very much before the operation, soon dried his tears when he found the slight prick was all that he had to undergo. Pasteur had a bedroom comfortably arranged for the mother and child in the old Rollin College, and the little boy was very happy amidst the various animals—chickens, rabbits, white mice, guinea-pigs, etc.

"All is going well," Pasteur wrote to his son-in-law on July 11: "the child sleeps well, has a good appetite, and the inoculated matter is absorbed into the system from one day to another without leaving a trace. It is true that I have not yet come to the test inoculations, which will take place on Tuesday, Wednesday and Thursday. If the lad keeps well during the three following weeks, I think the experiment will be safe to succeed. I shall send the child and his mother back to Meisengott in any case on August first, giving these good people detailed instruction as to the observations they are to record for me. I shall make no statement before the end of the vacation."

But as the inoculations were becoming more virulent, Pasteur became a prey to anxiety: "My dear children," wrote Mme. Pasteur, "your father has had another bad night; he is dreading the last inoculations on the child.

And yet there can be no drawing back now! The boy continues in perfect health."

Renewed hopes were expressed in the following letter from Pasteur:

Fig. 19.—Bronze statue of Jupille, a peasant boy attacked by a mad dog. He was treated, made a perfect recovery, and is today the "Concierge" of the Institut Pasteur in Paris. He is shown in his uniform, as he appears today, at the base of the monument that commemorates a tragic struggle that would have had a fatal termination, had it not been for M. Pasteur.

"My dear René, I think great things are coming to pass. Joseph Meister has just left the laboratory. The last three inoculations have left some pink marks under the skin, gradually widening and not at all tender. There is some

action, which is becoming more intense as we approach the final inoculation, which will take place on Thursday, July 16. The lad is very well this morning, and has slept well, though slightly restless: he has a good appetite, and no feverishness. He had a slight hysterical attack yesterday."

Pasteur was going through a succession of hopes, fears, anguish, and an ardent yearning to snatch little Meister from death; he could no longer work. At night feverish visions came to him of this child whom he had seen playing in the garden, suffocating in the mad struggles of hydrophobia, like the dying child he had seen at the Hopital Trousseau in 1880. Vainly his experimental genius assured him that the virus of that most terrible disease was about to be vanquished, that humanity was about to be delivered from this dread horror—his human tenderness was stronger than all, his accustomed ready sympathy for the sufferings and anxieties of others was for the nonce centered in the "dear lad."

OBSERVATIONS WITH VACCINES OF OTHER DISEASES.

If you are critical you may be wondering why these various preparations made in so many different ways are called vaccines, since that word comes from the Latin, *vacca*, a cow. Pasteur gave them that name in honor of the work of Edward Jenner, the discoverer of the use of cow-pox, or vaccine, for the prevention of small-pox.

Through these discoveries of Pasteur, the use of variously modified and attenuated micro-organisms for the prevention of disease became a recognized method of treatment.

M. Haffkine applied it with fair success for the prevention of cholera in India. Wright used it for the prevention of typhoid fever in the British Army in India. Later Haffkine used it for the prevention of the plague in India and elsewhere.

In our preparation for the recent war, every American soldier was vaccinated against small-pox, typhoid and paratyphoid fever, and many against cerebrospinal meningitis, influenza and pneumonia. The results were most satisfactory and impressive. In the enormous mobilizations there was practically no typhoid fever, a result very interesting to compare with the similar but comparatively very small mobilizations during our Spanish-American war, in which there was so much typhoid fever that more soldiers died of it than were shot in battle.

LIMITATIONS OF THE PROTECTION AFFORDED BY VACCINATIONS.

Before passing to other subjects it is necessary to call attention to the fact that not all diseases seem to be susceptible of either prevention or remediation by vaccines. Nor are all who receive them perfectly protected. Some of the soldiers vaccinated were made extremely ill, and there were a few cases of typhoid fever among the vaccinated. These are, however, only the exceptions, and are to be

thought of exactly as are the exceptions to the advantages of vaccination against small-pox.

ANTITOXINS.

Other aids in the prevention of infectious diseases are to be found in the antitoxins.

But these are not nearly so useful as the vaccines for the purpose of prevention, because there are so few diseases in which it is possible to obtain them in useful quantities. In only two diseases, diphtheria and tetanus, do they seem to be of real value. In the former they are useful for both treatment and prevention, in the latter for prevention only.

If some antitoxin could be kept in the blood of every child all the time, none would get diphtheria; if every wounded soldier could have immediately been injected with a large dose of antitoxin, none would have died of tetanus.

DIFFERENCES BETWEEN THE ACTION OF VACCINES AND ANTITOXINS.

Vaccines and antitoxins have nothing to do with one another.

The vaccine is composed of the actual germs of the disease, given to the patient for the purpose of giving him a mild illness—provoke a reaction—that will result in the appearance of the subsequent pro-

tection as explained. When the patient thus reacts, he prepares his own defensive substances, and the effect is usually lasting in proportion to the severity of the reaction.

The antitoxin is a vicarious product. It is serum taken from the blood of a horse or other animal that has been made to react again and again to the introduction of micro-organisms or their products, until its blood is surcharged with the defensive substances, that we then transfer to others.

The patient receiving the antitoxin does nothing to help himself, and is protected only so long as the introduced substance remains, which is never very long.

Where it is possible to make a choice, the preference is always greatly in favor of the vaccine, because of the greater permanence of its effects.

The difference between the two might be compared to having the people of the country prepare to defend it, and hiring foreign troops to do it. In the latter case the strength would disappear with the departure of the mercenaries. In the former, the strength would remain for a generation.

SAVING THE SCHOOL CHILDREN.

The employment of the antitoxin of diphtheria for the purpose of preventing the occurrence of the

disease in asylums and schools, in which the children have been accidentally exposed to infection through the unexpected occurrence of the disease in one of them, is very successful. If all of them are given a small dose of antitoxin, they usually entirely escape the disease, for as long a time as the remedy remains in the blood, which is not a fixed period, but usually only a few weeks or months. Fortunately, it is usually long enough to tide over the period during which there is danger either from the patient, or from any carriers that may have occurred among the well children. But when this beneficial effect has "worn off," every child is back again in the same condition of susceptibility as that in which he was at the beginning. No permanent good has been done. How much better it would be if he could be brought into a condition similar to that resulting from the effect of a vaccine! With animals it is easy to do this. The horses that make the antitoxin used in treating those ill with diphtheria, are repeatedly injected with increasing quantities of the diphtheria toxin until they endure without injury, almost a thousand times as much of the poison as would have originally killed them. If we could only effect the same similar resisting power in the children! But to attempt anything similar would be to subject them to the danger of becoming paralyzed

from the ill effects of the diphtheria toxin upon the nerves.

However, as early as 1895, Prof. Babes, of Bucharest, discovered that if an animal were injected with a mixture of toxin and antitoxin so proportioned as to be harmless in itself, that animal would proceed to make antitoxin as readily as though it had received the diphtheria toxin by itself and in its usual injurious form. Perhaps it might be possible to apply this method or some modification of it to the children with good effect.

For twenty-five years, studies and experiments have been going on in the laboratories of the New York Department of Health, and in some of the private and public schools and asylums of New York, under the direction of Dr. W. H. Park, one of America's best bacteriologists, and with a success that is most gratifying. When an experiment extends over twenty-five years, is conducted by capable men and includes observations made upon 180,000 children, it certainly merits careful consideration. And this is what has been found:

> Three injections of 1 cubic centimeter—15 drops—each, of a suitable toxin-antitoxin mixture, spaced one or two weeks apart, will cause about 85 per cent. of susceptible children or older persons to develop sufficient antitoxin to give the negative Schick reactions and produce marked, if not absolute, protection against diphtheria.

The duration of the immunity in at least 90 per cent. of the children is for more than six years, and probably for the remainder of life. There seems to be no difference in this respect between these, and those who develop antitoxin naturally.

The toxin-antitoxin injections are inadvisable before the age of 6 months. During this time most of the infants retain the antitoxin received from their mothers. Up to the age of three months, immunizing injections are usually ineffective, as the infant tissues do not respond sufficiently during this period to the toxin-antitoxin to produce antitoxin. Under usual conditions, it is probably safe to wait until the infant is nine months old, and then to give the injections at the first suitable occasion. During the first three years there is almost no annoyance from the injections. As the child grows older, the danger from diphtheria gradually lessens, and the percentage of those developing annoying local and constitutional reactions slowly increases.

Institutions in which the children have been given the immunizing injections have been remarkably free from diphtheria.

The school-children who have been injected have had *one fourth as many cases as the untreated children, and these have been of less severity.*

There seems to be good reason to believe that with the added experience of the future, through the judicious employment of this, or some similar means of sorting out the susceptible children and immunizing them to diphtheria, it may be possible to actually stamp out this dreadful disease.

THE PREVENTION OF DISEASES WHOSE MICRO-ORGANISMS ARE TRANSMITTED BY INSECTS.

As we pass from diseases directly communicable from individual to individual or indirectly communicable through fomites, to those transmitted only by insect vectors, all of the problems change, and complications arise. The patient ceases to be the important source of danger, and may be approached without hesitation. I have studied typhus fever in Glasgow, yellow fever in Panama, and have made an autopsy upon a case of African lethargy without being in the slightest danger of infection.

To get typhus fever one must be bitten by infected lice; to get yellow fever, by infected mosquitoes; to get African lethargy, by infected tse-tse flies, etc.

THE TRANSMITTING INSECTS ARE THEMSELVES ILL.

I hope that it is quite clear to all that there is nothing dangerous in the bite of a louse, a mosquito or a tse-tse fly, *per se*. The danger is not from the insect, but from what it carries in it; not from a well insect, but from an ill one. The insects can no more

create the micro-organisms of disease than we can. They are the unfortunate ones that have themselves become infected with the germs of disease taken in the blood of animals or humans they have bitten.

Whether the insect vectors are "ill" in any sense that is comparable with illness as we understand it is problematical. The flea infected with the plague is. But how much the insects suffer, or whether they frequently die of the infections we are not sure. Dr. Yersin thought that he saw a fly die of infection by the plague bacillus. We use the term "ill insect," therefore, solely to emphasize the difference between an insect that is infected and others that are not. Perhaps it should be pointed out, in passing, that if these infected insects commonly died, the transmission of the parasites would be interrupted, and the species die out. Nature is too cunning in her adaptations to permit that to happen; the species must be maintained.

PREVENTING DISEASES COMMON TO MAN AND INSECTS ONLY.

In this group of affections we come upon the curious phenomenon of insects (arthropods) infecting themselves from men, to subsequently infect other men by whom other insects will become infected to infect still other men, and so on forever.

I am often asked, by students, who began it; but the question is just like the one about the egg and the bird. Did the first bird come out of an egg, or did the first egg come out of a bird? It doubtless began before either the men or the insects were what they now are, in the long ago of evolution time.

But with reference to these diseases we can be sure of one thing; if there were no more men ill with them, there could be no further infection of insects, and if there were no more insects infected there could be no more ill men. Upon theoretical grounds, therefore, the extermination of the disease requires either the destruction of all the sick men or of all of the sick insects. But we can not kill our unfortunate fellow beings and it is impossible to kill all of the insects. How shall we go about it?

YELLOW FEVER.

The specific micro-organism causing yellow fever is probably the *Leptospira icteroides,* a tiny spiral micro-organism, found in the bloods of cases of yellow fever, at Guayaquil, Ecuador, by Dr. Hideyo Noguchi of the Rockefeller Institute of Medical Research. It is infective for guinea-pigs, and can be transmitted to them by the bites of mosquitoes that have bitten human beings suffering from yellow fever. In the experiment animals it induces a febrile

disease to all intents and purposes corresponding with the human disease.

The idea that yellow fever was caused by the bites of mosquitoes is very old, and to its proof the late Dr. Charles J. Finlay of Havana devoted himself

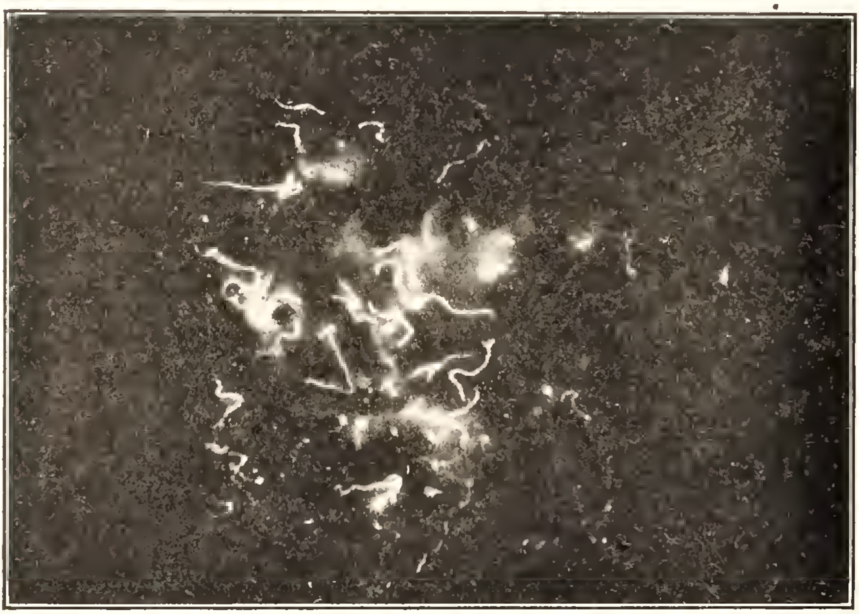


Fig. 20.—Leptospira icteroides. (*Noguchi.*)

The micro-organism supposed by Dr. Noguchi to be the cause of yellow fever. The delicate screw-like organisms were photographed alive under a dark field illuminator, magnified about 1000 diameters.

for many years. But the final proof of it came in 1900 when Reed, Carroll, Lazear and Agramonte made their investigations in Cuba. Through their efforts it became established that only one species of

Major Walter Reed, U. S. A.

Lieutenant James Carroll.

Dr. Jesse W. Lezea

Dr. Aristides Agramonte.

Fig. 21.—The members of the Yellow Fever Commission, who in 1900 succeeded in proving the mosquito to be the transmitting agent of the micro-organism of yellow fever.

mosquito, *Stegomyia* (or *Aëdes*) *calopus* can carry the infection.

This insect is peculiarly a town and house pest. It breeds in cisterns, rain barrels, gutters, and pools of fresh water. As is the case with mosquitoes generally, only the female bites, and it seems as though the bite that infects is usually given between about five o'clock and midnight.

Stegomyia is only found in hot countries, and is quickly killed by frost. It seems never to live at altitudes above about 3000 feet. In the summertime it may be carried by ships, and perhaps by trains to points out of its normal geographical distribution, where it may live so long as the temperatural and climatic conditions are favorable.

When a Stegomyia is fed upon the blood of a yellow fever patient it seems that the imbibed microorganisms undergo some change in its body, or effect some kind of a migration that is only completed after about twelve days. Up to that time it seems to be harmless; after that time it is infective and remains so as long as it lives. It seems to be impossible for a mosquito to bite the sick man and then immediately to infect another.

The spread of the disease and the occurrence of epidemics, then, depend upon the fact that a patient suffering from the disease arrives where there

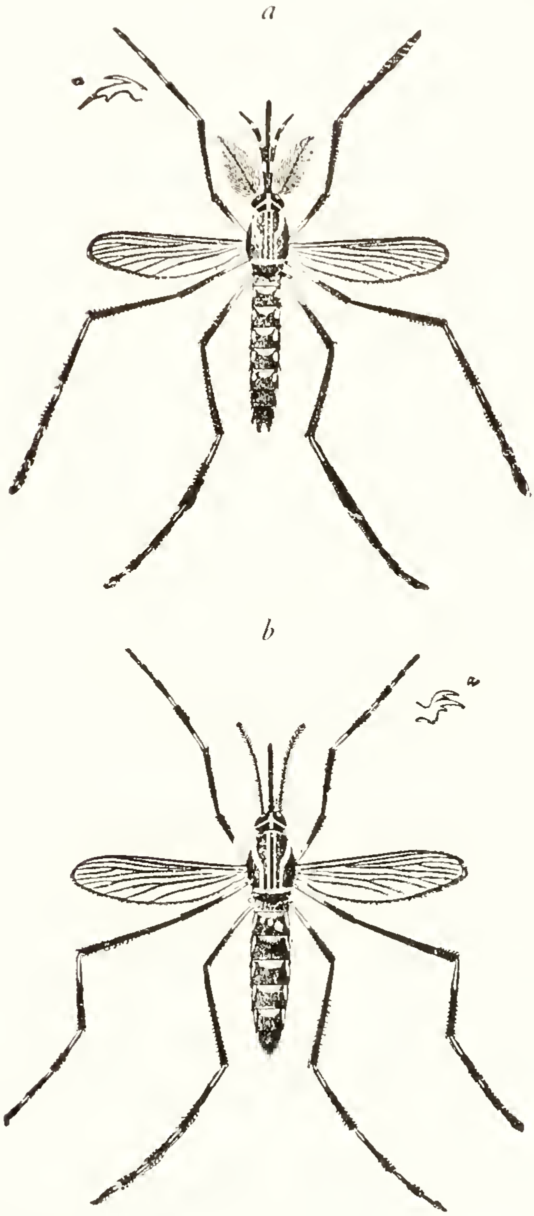


Fig. 22.—*Stegomyia fasciata* (*Stegomyia calopus*): *a*, male; *b*, female (after *Carroll*).

The mosquito that transmits the micro-organism of yellow fever. The upper figure is the male, that does not bite, so that the whole responsibility rests upon the female shown below.

are Stegomyia mosquitoes which he infects so that they can spread the disease, or that infected Stegomyia mosquitoes arrive where they can bite men. Sometimes, no doubt, both arrive at the same time and in the same conveyance.

For example, there are ordinarily no Stegomyia mosquitoes in Philadelphia, because they are unable to survive the rigors of our climate. But vessels coming from the south, with cargoes of fruit, may occasionally bring them in the summer time, and then they may remain, breeding in pools of water, and perhaps even becoming quite numerous until the frosts of beginning winter kill them. If while thus present, another ship should bring in a case of yellow fever, there would be no essential difference between our city and the native home of both the yellow fever and the mosquitoes, and the disease could and probably would spread. It was no doubt just such a circumstance that made possible the great epidemic of 1793.

To prevent a disease of this kind it is necessary to devote attention to both the insects and the patients.

Let it be supposed that a case of yellow fever is brought into the Delaware River in the middle of the summer. It should at once occur to you that it would not do to permit him to land, contenting our-

selves with the thought that Stegomyia mosquitoes do not live here, for they may be here, as past experience goes to show. If he is to land it must be only after arrangements are made to so protect him from the possibility of being bitten on his way to the hospital, and after he arrives at the hospital, as to make the infection of the mosquitoes impossible. If that is done there is no further danger from him. But while we are thinking of the patient, it will not do to disregard the mosquitoes that may have arrived with him, and already be infected. It is improbable that they will be on the outside of the ship, as they would have, in all probability, been blown off at sea, but they may be inside among the bananas or other cargo. To make sure that they do not escape it may be necessary to fill the unopened hold of the ship with a poisonous gas that will kill them.

But suppose that with or without all of these precautions it is found that cases of yellow fever are springing up along the water-front, showing that infected mosquitoes are abroad? Then it will be necessary to amplify the precautions. It will be of prime importance to seek out and drain or kerosene the possible breeding places of the mosquitoes, to screen houses, and to immediately protect and remove every case of the disease to a screened hospital.

Not to go further into details, I am sure that it is evident to you that it is much more easy to keep the disease out than to eradicate it when once it is in the city. This is the great lesson to be learned about all epidemic diseases. It is carelessness in this particular that is the cause of most of our troubles. It is of prime importance to every city to which yellow fever may come, to see that there are none of the mosquitoes to transmit it when it does come. That this is possible it is only necessary to note what has been done at Panama, in Cuba, and in New Orleans.

In all of these places yellow fever was, in the past, common and fatal, but through energetic mosquito extermination each has been made reasonably safe both for its own inhabitants, and its visitors.

But the good effects resulting from mosquito extermination are not limited to so rare a disease as yellow fever in northern cities. They are as well shown in the prevention of the other mosquito borne diseases. A campaign against mosquitoes for the purpose of preventing yellow fever, brings immediate benefit through the simultaneous prevention of dengue fever, and a great diminution in the number of new cases of malarial fever, and makes life more tolerable and property more valuable.

DENGUE FEVER.

The specific cause of this disease has not yet been discovered. But it is pretty definitely established that it is transmitted by mosquitoes. Not by a single species, as is the case with yellow fever, but by several. *Stegomyia calopus*, and *Culex fatigans* seem to be thoroughly incriminated, but there may also be others.

These mosquitoes have much the same geographical distribution, *Culex fatigans* probably being a little more widely distributed, having a slightly greater tolerance for cold. It is therefore possible to have the dengue fever wherever it is possible to have yellow fever, and it is quite common for the two diseases to occur together. It is worth remembering, however, that wherever dengue fever occurs, there may be danger of yellow fever, so that an effort should be made to exterminate the mosquitoes.

MALARIAL FEVER OR PALUDISM.

The micro-organism that causes this disease was first observed in the blood of human patients by Dr. Charles Louis Alphonse Laveran, a French physician working in Algeria, in 1880, and was named by him *Plasmodium malariæ*. These tiny

micro-organisms, of which several species are now known, attach themselves to, or enter into the red blood corpuscles, which they devour, gradually growing larger until about the same size, when they segment, or divide into a number of spores, differing in appearance in the different species. Each spore

Fig. 23.—Charles Louis Alphonse Laveran, the discoverer of the parasite of malarial fever.

then enters into a new corpuscle in which it grows to maturity giving rise to new spores, to continue the cycle indefinitely. Though Laveran saw all of the various stages in the development of the parasites, it was not until some years later that an Italian investigator named Golgi put them together and described the *human cycle* of the development of the parasite.

Each time that the little parasites sporulate, their numbers increase. Hence, the longer the disease continues the worse it gets until the human being begins to assert his defensive energies, after which it may continue for a long time without doing much more damage.

There are three species of malarial micro-organ-

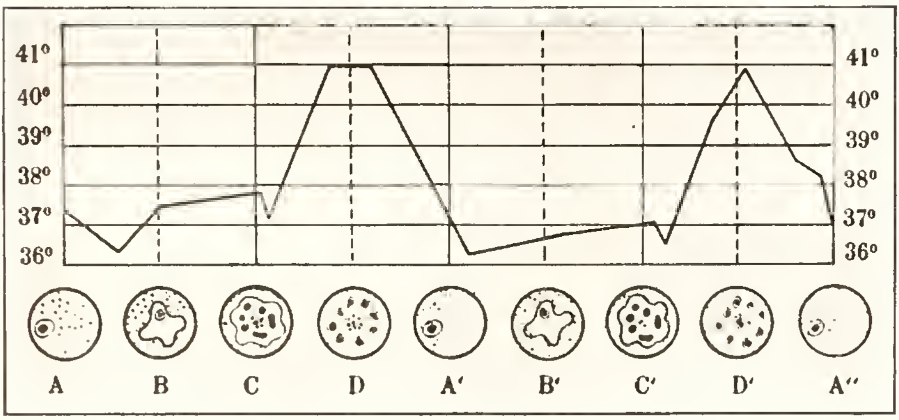


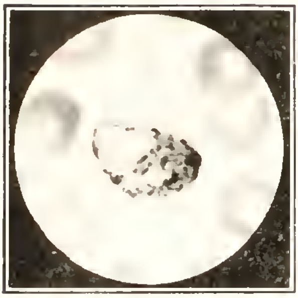
Fig. 24.—Human cycle of tertian malaria.

In the circles *A*, *B*, *C*, *D* and *A'*, *B'*, *C'* and *D'*, which represent red blood corpuscles, malarial parasites are shown growing from the little spore in *A* and *A'* to the adult in *C* and *C'* and sporulating in *D* and *D'*. Above is a temperature curve, the figures on the left indicating the temperature of the patient (given in the centigrade scale) the vertical lines indicating days. The temperature is highest—*i.e.*, there is a paroxysm—each time the parasite reaches the stage of sporulation, *D* and *D'*.

isms, and the differences that obtain among them partly explain the manifestations of the different clinical forms of malarial fever. The best known, and probably the most frequent in occurrence,

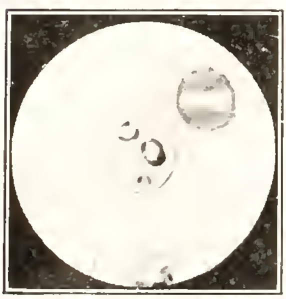
though the frequency varies in different localities, is probably the *Tertian fever,* in which the chills, fever and sweat that mark the paroxysms come on every third day. The parasites of this variety sporulate every third day, the beginning of the sporulation corresponding with the onset of the paroxysm. A second but much more rare form of the disease is characterized by paroxysms that recur every fourth day and is called *quartan fever.* Its parasites segment or sporulate every fourth day, the phenomenon again corresponding with the onset of the paroxysm. The third and remaining variety of the disease is known as *aestivo-autumnal* or tropical fever, and has no regularly recurring paroxysms, but a more continuous fever. Its parasites do not segment at the same time or at regular intervals as in the other cases.

The fact that these micro-parasites undergo a cyclical development, added to their characteristic appearance shows them to be *protozoa*—animal micro-organisms. They are sometimes so numerous that in the most severe forms of infection every red blood corpuscle has one or two parasites in its interior. They circulate with the blood corpuscles, find their way to the spleen, brain, bone-marrow, and other internal organs where they may be detained in the endothelial cells of the capillaries, but



Plasmodian vivax. An adult parasite of tertian fever of man.

Plasmodian malaria. The adult parasite of quartan fever of man.



Plasmodium falciparum. The parasite of aestivo-autumnal malarial fever showing the tiny ring forms.

Plasmodium falciparum. The parasite of aestivo-autumnal malarial fever. Adult cresanter form.

Fig. 25.—The various malarial parasites of man.
(*Kolle* and *Wassermann.*)

under no known circumstances do they seem to leave the blood.

From the parasitological point of view, two mysterious things bothered the earlier scientific investigators; first, the absence of any satisfactory explanation of their entrance into the body; and second, the absence of any means by which they could get out of the body to infect new hosts. But the first did not trouble them so much as the other for it was conceived that the micro-organism might enter the body in drinking water, or even by inhalation.

Exactly the same difficulty presented itself with regard to an embryo worm—the filarial worm—observed years before. Considerable numbers of the creatures were found wriggling in the streaming blood, but they seemed to go nowhere in particular, and did not leave the body. About 1878, it occurred to Sir Patrick Manson that Nature might provide for future generations of the worm by having it taken from the blood of one man by some biting insect that then transferred it to another. Letting mosquitoes bite patients with the embryo worms in the blood, Manson was able to show that in the insect a further development of the parasite took place, after which it encysted itself in the muscles about the root of the proboscis.

Later, his pupil, Dr. Low, was able to show that when insects, with the worms so encysted, bit a human being, the warm blood ascending the proboscis excited the worms which became active, left their cysts, and wriggled down the proboscis of the mosquito into the blood of the new host.

Fig. 26.—Sir Patrick Manson.

A distinguished authority upon all matters pertaining to tropical medicine, and the founder of the London School of Tropical Medicine.

In thinking about the malarial parasite, Manson came to the conclusion that it also must depend upon a biting insect for its transmission to new hosts. Another of his pupils, Major Ronald Ross, was at that time about to go on to India, to be attached to a military post, and Manson suggested

that he try to solve this important problem while in that coutry where the conditions would probably be favorable. After many painstaking efforts and as many heart-breaking disappointments, Ross was successful.

Fig. 27.—Sir Ronald Ross.

Working in India, upon a malarial parasite of small birds, Ross discovered the part played by the mosquito in transmitting the malarial parasites, and worked out the life-history of the parasites in the insect host.

For this discovery, Major Ross, now Sir Ronald Ross, was awarded the Nobel Prize in 1902, which be richly deserved. Some of you that read this book may find it a bit technical, but I feel sure that you will all be interested, delighted and profited if you read the Nobel Prize Essay upon "Researches on Malaria" published in the English language in

Stockholm, in 1904, and to be found in most of the large libraries. Its chief value to you may not lie in the knowledge of malarial fever that you would derive, but from the lesson concerning the methods used and the patience required in the prosecution of a scientific research. There were many points in his investigations at which any lesser man might have stopped with dignity, considering that an important new observation had been made, and that he had distinguished himself; but Ross was made of sterner stuff. His mind grasped the full significance of the problem, and with perseverance worthy of a Briton, and attention to detail equalling that of a Teuton, he continued until all was finished and the means of malarial transmission understood, and its prevention made a possibility.

I wish that I could give you all this through extracts from the original writing, but that is impossible because of the simple and continuous character of the narrative which baffles condensation. You must read it for yourselves. I cannot forebear, however, to quote two brief extracts, one exemplifying the patience of the investigator, the other the disadvantages and disappointments under which he labored.

I therefore commenced a long series of differential experiments in order to establish the fact thoroughly. Gray

mosquitoes, bred from the larva in captivity were fed (*a*) on birds with Proteosoma— a malarial parasite of birds—and (*b*) on birds without Proteosoma, and the results compared. . . . Out of 245 gray mosquitoes fed on birds with Proteosoma, 178, or 72 per cent. contained pigmented cells, while out of 249 of them fed on blood containing other parasites or no parasites, not a single one contained them.

Aside from all else that was done, can any of you imagine what it meant to dissect and microscopically examine the tissues of nearly 500 mosquitoes for these "pigmented cells?" Remember no one had blazed the trail he was following. His was the virgin soil!

Just at this time I wrote to Manson, in a state of unbounded delight, that he might expect to know the full history of the parasites of malaria in the mosquito within a few weeks.

Next day, however, I received telegraphic instructions from Government, ordering me to proceed forthwith to Kherwara in Rajputana—a place a thousand miles distant! . . . It would be difficult for others to understand the effect of this cruel blow. Here in Secunderabad I had numerous cases of malaria in my own hospital, and, moreover, the men had been trained to submit to mosquito bites—a matter often of some difficulty with the superstitious natives of India. I had also experienced assistants hired by myself for the work; and above all, the proper kind of mosquitoes, including their larvae, just found in abundance.

There is no doubt whatever that, had I been left at Secunderabad, I could easily have traced the whole life history of the human parasites in the dappled-winged mosquitoes within a few weeks. But at Kherwara I did not

know what would happen. It was in the north; winter was approaching; and I knew that mosquitoes would refuse to bite in the cold. I failed even to guess the reason for this sudden transfer. The astonishing discovery of the pigmented cells had been officially and fully reported to the Government through the chiefs of my own department: malaria is the most important disease in India; and I thought that my superiors were taking the greatest possible interest in researches that touched so vital a subject—I thought that they would make every effort to leave me undisturbed, if they did not give me active help.

But the orders were peremptory and not to be discussed. Within two days, I was on the week's journey to Kherwara. I only saw one gleam of comfort. It was impossible that my chiefs, medical men, would consent to interrupt my work at such a moment. There must undoubtedly be a bad outbreak of malaria at Kherwara which would throw great light on my subject.

When I arrived at the place, however—a pretty station with three or four Europeans—I was told that there was no malaria there: there had not been a case for months!

This, then was my Elba—almost my *Ile du Diable;* and I saw no prospect of escaping for a year at least. . . . I wrote officially to my superiors asking to be allowed to return to Secunderabad to continue my work; but received only a reprimand in consequence.

But the good genius of his inspiration was Manson who watched over his work, and to him he wrote his troubles:

I had, of course, given full details of my transfer to Manson, and he exerted himself to influence the Government of India, and the Director-General of the India Medical Service . . . to put me on special duty to continue my researches. . . . I now received a telegram that I

had been placed on special duty to investigate malaria and kala-azar in Calcutta and Assam. My five months' imprisonment was at an end . . . but here I was met by an unexpected and most unforeseen misfortune. The plague had been raging in all this time in India; and the Government was trying to introduce Haffkine's prophylactic inoculations in Calcutta. Just before my arrival, serious riots, during which many of the Europeans had felt themselves obliged to go about armed with revolvers, had occurred. The ignorant populus, thinking that the British were trying to inoculate them with the plague and not against it, flew into paroxysms of terror at the very sight of a European *hakim* (physician), while anything remotely resembling inoculation made them frantic. The physicians of the Calcutta Hospitals were evidently very unwilling that I should use their cases for my experiments under these circumstances; and, as I had no hospital of my own as in Secunderabad and Bangalore, I was forced to send my assistants into the bazaar (native parts of the city) in order to try to induce patients to come to me on payment. Calcutta is not very malarious, especially at that time of year, and it was only on large payment that several beggars with fever were induced to come to me; but when I proposed to prick their fingers in order to examine their blood they generally left their money, took up their crutches, and fled without a word!

His final observations were for this reason, made, not upon the parasites of human malarial fever, but upon those of a similar disease (Proteosoma disease) of small birds. He found that when mosquitoes of a certain kind were permitted to suck the blood of birds whose blood contained the parasites, the latter underwent a peculiar change in the in-

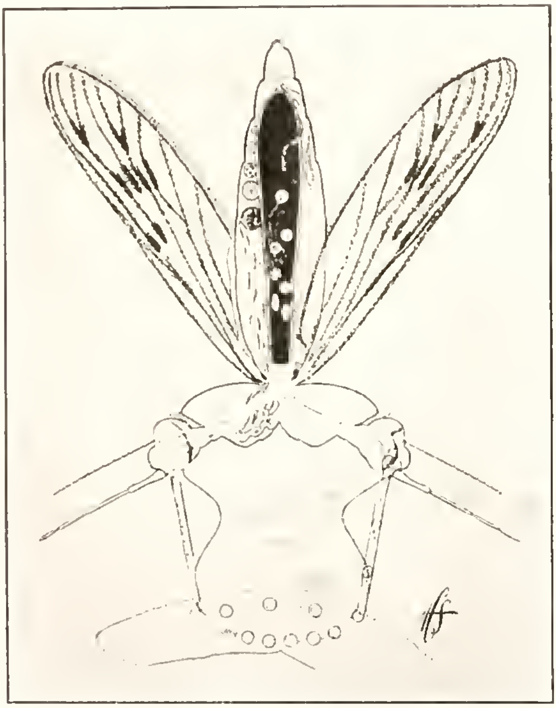


Fig. 28.—Cycle of parasitic development in the mosquito. (*Stryke.*)

The diagram shows a mosquito with two heads, each biting a human finger the outline of which is shown below. In the finger, in a series of little circles representing human red blood corpuscles; the malarial parasites are represented in the various stages of the human cycle. The mosquito head directed to the right is seen to be sucking up blood corpuscles containing the adult parasites, many of which in the further modifications undergone in the mosquito's body can be seen in white, on the black background of the stomach. From the stomach they escape, attaching to its outer wall on the left hand side, and finally eventuating in tiny filiform bodies, the sporozoites, that can be traced to the insect's thorax, and then down the proboscis of the head directed to the left, from which they enter the human finger to infect new blood corpuscles. The interval between the bites inflicted by the two heads is supposed to be from ten days to two weeks, accordingly as the weather is warmer or cooler.

sects' stomach. In a short time they penetrated the wall of the stomach, and attached themselves to its outside, where they slowly grew to be large cells in which, after various intermediate steps, a great number of very tiny bodies of a long spindle shape were formed. When these were fully devel-

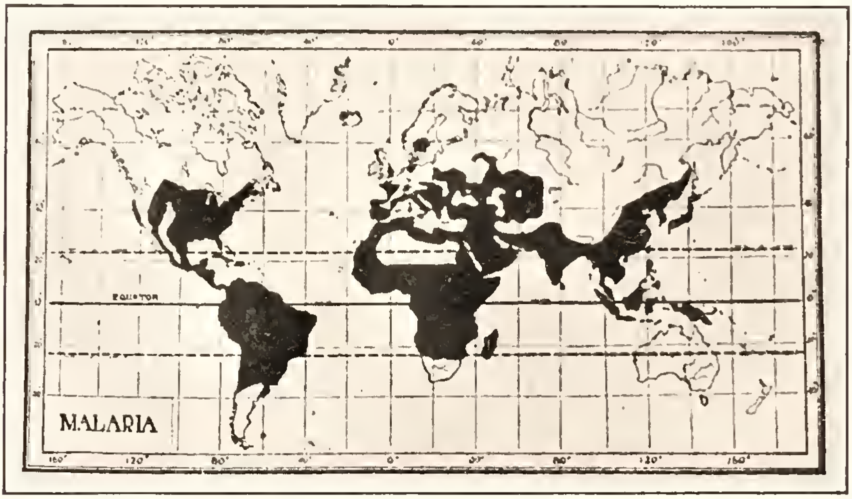


Fig. 29.—Map showing in black, the geographical distribution of malarial fever throughout the world. (*Stitt.*)

oped, the wall of the cyst ruptured, and they escaped into the general body cavity of the insect. Many of them were to be found a little later in the salivary glands, from which they passed into new birds as the mosquitoes bit them. This cycle of development in the mosquito required about eleven days.

What was true of the malarial parasites of the birds proved later to be true of the parasites of

man, and every subsequent investigator has fully confirmed Ross's findings. There are, then, two distinct cycles of development for malarial parasites: one in the human host by which the parasites increase immensely in numbers so as easily to be taken in the drop of blood sucked by the mosquito, and another in the mosquitoes, by which

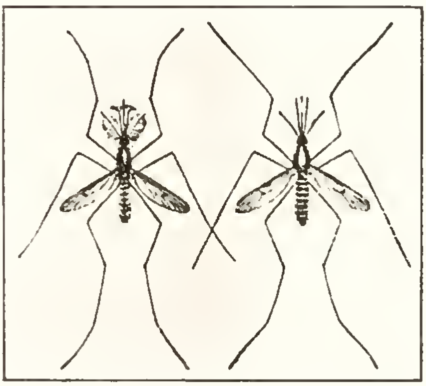


Fig. 30.—Male and female anopheles maculipennis. (*Howard.*)

The mosquitoes that most frequently transmit malarial fever. As usual, the male, on the left, does not bite, so the whole responsibility rests with the female on the right.

they are prepared for transmission to new human beings.

Ross and all of his successors find the same thing; only certain mosquitoes, mostly of the family Anophelinæ, seem capable of acting as the definitive hosts of the parasites. But of these mosquitoes there are numerous genera and many species, widely distributed throughout the world.

Indeed, there is scarcely any part of it where they may not be found, and therefore scarcely any part of the world where there is not or may not be malarial fever.

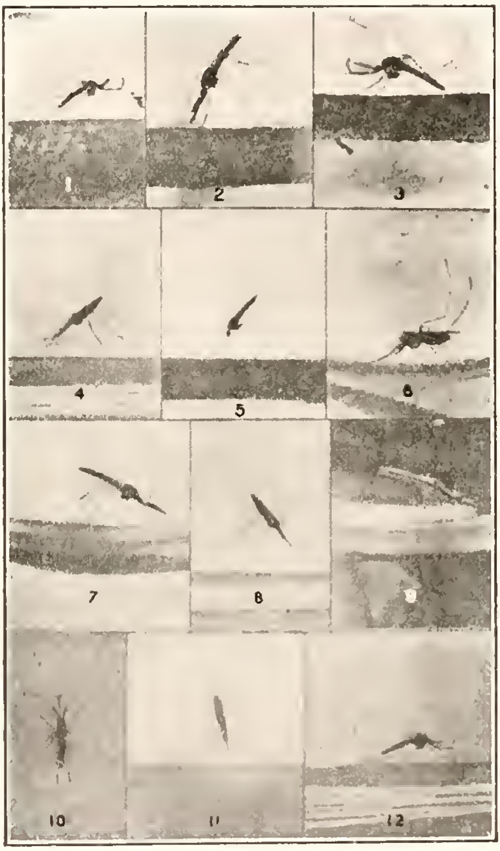


Fig. 31.—Photograph of various genera and species of mosquitoes to show the characteristic poses. 1, 3 and 6 are species of Culex; 2, 4, 5, 7 and 8 of Anopheles. Notice that Culex is a kind of hunch-back, and that Anopheles is straight; also that the bodies of the culices are fairly parallel with the surface upon which they rest, and that of the Anopheles forms a sharp angle. (*Giles.*)

When one stops to consider the peculiar and complicated conditions that must be met before one

can become infected with malarial fever, he can but wonder that so many cases of the disease occur: A mosquito of a certain family—the Anophelinæ—must imbibe blood containing the malarial parasites; after an interval of about eleven days, dur-

Fig. 32.—Mosquito-breeding pools along the roadside.

(From Deaderick, "A Practical Study of Malaria.")

ing which time the mosquito is harmless, it must bite to introduce the parasites into the new host. But once having become infectious the mosquitoes remain so throughout the remainder of their lives—a hundred days or more.

The Anophelinæ are mosquitoes that breed by preference in clear water, and often in running

streams if there be vegetation along the banks to shelter them. The adult females are usually inactive during the day, and begin to fly about twilight. Their biting is usually done either at that time or in the early part of the night.

WHAT CAN BE DONE TO PREVENT THE OCCURRENCE OF MALARIAL FEVER.

Now when a disease is transmitted by a single species of mosquito it may be comparatively easy to prevent it, especially if as is the case of the mosquitoes of yellow fever and dengue fever, it be chiefly a domestic and easily get-at-able insect; but when many species are concerned, and when they are widely distributed and fly chiefly at night, it may be more difficult.

The matter is difficult in proportion as the population is scattered, the district favorable to the anopheles mosquitoes, and the number of human beings and mosquitoes already infected great.

I. Let the matter be first considered from the standpoint of the mosquitoes. The greater the number of infected anopheles mosquitoes, the greater the probability of infection. If, however, the mosquitoes can be avoided, it is possible to escape malarial infection almost indefinitely. This is well shown by the pioneer investigations of Drs.

Sambon and Low, who went to one of the most pestilential districts of the Campagna Romana, especially selected because of its bad reputation for malarial infection, built for themselves a mosquito proof house, and taking advantage of the known

Fig. 33.—The mosquito-proof house on the Roman Campagna, in which Drs. Sambon and Low lived for several months, during the moist malarious time of the year, without acquiring the disease.

habits of the anopheles mosquitoes, went abroad only in the daytime, and retired to its shelter shortly before twilight. By these simple means they were able to remain there for three months during the most malarious time of the year, in complete safety.

If, therefore, the mosquitoes can be avoided, malarial fever can be prevented. A prime factor, therefore, in preventing malarial fever, is the avoidance of the infected mosquitoes, by observing times and places where they occur and the judicious use

Fig. 34.—Mosquito-breeding pools in the borrow pits along a railroad.

(From Deaderick, "A Practical Study of Malaria.")

of mosquito wire and nets, and a careful extermination of all of the insects already in the house.

But as the number of infected insects is constantly being recruited, it becomes very important to eliminate as many of the insects as possible

through proper ditching, draining, cleansing and kerosening of their breeding places.

The greater the diminution in the number of in-

Fig. 35.—Where mosquitoes breed by millions. (*Howard.*)

sects, the less the danger of infection. When the population to be protected is concentrated in cities and towns the extermination of mosquitoes may be fairly easy through co-operative efforts, but where it is scattered through a sparsely settled country it

may be extremely difficult. But it ought never to be regarded impossible except among savage people. Anopheles mosquitoes are not long fliers, and the elimination or oiling of breeding places about individual houses—rain barrels, stock pools, sluggish streams with vegetation along the banks—will do much to relieve local conditions, and the more widely this work can be extended, the more useful it will be. The fewer the breeding places the fewer the mosquitoes; the fewer the mosquitoes the fewer infected; and the fewer infected mosquitoes the fewer the transmissions.

II. The second factors to be considered are the infected patients.

So long as they are easily accessible an ever greater number of mosquitoes become infected. As a moment ago it was shown important to prevent infected mosquitoes from biting, lest the human be infected, it is now imperative to prevent them from biting lest they themselves become infected. The means to the ends are the same, and again must be emphasized the importance of mosquito wire screens at the doors and windows of the houses, and surrender of the personal liberty of any of the inhabitants known to be infected, who must remain indoors during the time the anopheles fly. If these measures could be consistently carried out, there

might be no infected insects, and therefore no new cases after a single season.

III. Another means that will contribute to this end is the routine microscopic examination of the blood of every individual in the community for malarial parasites, followed, first, by the temporary isolation of the infected individuals to prevent the infection of the mosquitoes; and, second, by effective treatment for the destruction of the parasites in their blood.

All this goes to show that for the extinction of malarial fever co-operation on a large scale is necessary and that the execution of the approved measures should be in the hands of some recognized authority whose duty it will be to see that they are consistently carried out. The extraordinary success that may accrue under what seems to be most unfavorable conditions, is shown by the achievements of the United States officials during the building of the Panama Canal. The Isthmus was notoriously infected by a very fatal form of malaria—Chagras fever. The death, from this cause, of so many of the workmen employed by the French company, by whom the excavation of the canal was first undertaken, was one of the chief factors that led to the abandonment of the enterprise. But the anti-malaria campaign of the United States

authorities, carried out through the initiative and energy of the late Col. W. C. Gorgas, along the lines outlined above was so successful that the canal

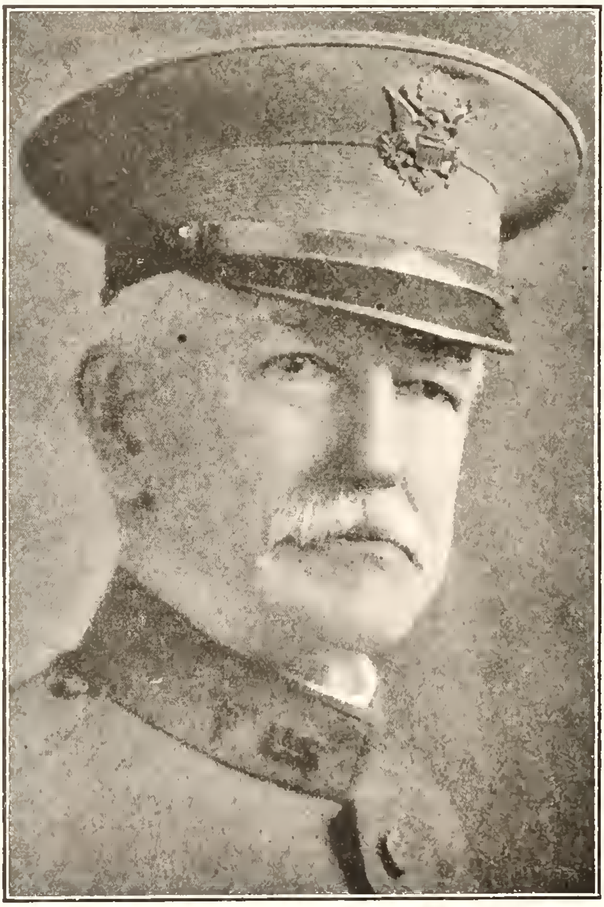


Fig. 36.—Major General William C. Gorgas, Late Surgeon General, United States Army, whose successful sanitary work at Panama, probably made possible the building of the Canal.

was not only completed without much loss of life, but the whole Isthmus was transformed from a pestilential district to one not only perfectly safe, but

almost salubrious. Visitors and residents in the canal zone need no longer fear either yellow fever nor malarial fever.

At Camp Beauregard, where, as I have said, I was stationed a part of the time during the war, there were 29,000 soldiers, from Mississippi, Louisiana and Arkansas, all sections of the country well infested with malaria. The camp itself was in the central part of Louisiana, a few miles from the city of Alexandria. It was surrounded by forests, filled with streams and pools in which anopheles mosquitoes breed abundantly. Many of the soldiers were infected when they arrived at the camp. Conditions were in every way favorable to the rapid outbreak of the disease in epidemic and perhaps pestilential form, yet there were very few cases.

So soon as the camp was laid out, squads of men under the orders of the sanitary officer, were employed in ditching and draining, while others with tanks of coal oil on their backs proceeded to find and oil all the pools in and near the camp and its base hospital. Thus the number of mosquitoes was reduced to a minimum. Every case of "chills and fever" was immediately sent to the base hospital and carefully treated, and as the entire hospital, including the walks from one building to another, was enclosed in mosquito wire, the pa-

tients were never exposed to the attacks of mosquitoes. Later, the blood of every soldier in the camp was examined by his regimental surgeon to determine whether he was a carrier of the disease, and if so he was at once subjected to energetic treatment for the destruction of the parasites in his blood. Through these means it was possible to maintain a large body of troops in good health, where a few years before a great number of cases of malarial infection must inevitably have occurred.

Perhaps an additional word ought to be said about the malaria carriers to whom reference has been made. They are persons who have had and recovered from the disease, but in whose bloods a certain number of the parasites still remain in the form known as *gametocytes.* Such persons may at any time suffer a relapse, or if they do not, may serve to infect mosquitoes.

TYPHUS FEVER.

The micro-organism that causes typhus fever is unknown. It has not yet been seen either in the human being or in the louse which transmits it. There are good grounds for assuming that it is too small to see, and by many it is included among the invisible filterable viruses. In regard to this parasite, however, we meet for the first time with

a new fact in parasitology. In no case has it been found that the offspring of infected mosquitoes can transmit malarial infection. But the parasites of typhus fever entering the body of the louse that has bitten the infected patient, in part pass through its eggs to its offspring, so that both the originally infected insect and its descendants become able to transmit the infection.

However this does not greatly complicate the problem of prevention, for it is impossible to get rid of lice unless their eggs be destroyed. It is on this account that lice in the hair can never be successfully eradicated by the use of the comb.

Lice of the species known as *Pediculus capitis* and *Phthirius inguinalis*, live in the hair; of the species *Pediculus vestimenti*, in the clothes. The former carefully cement their eggs to the hairs, the latter to the fibers of the clothing. In no case do the eggs fall off and get lost. All lice feed upon the blood of the host, and with it take into their bodies any parasites it contains.

The prevention of typhus fever resolves itself into the very simple circumstance of getting rid of lice—delousing.

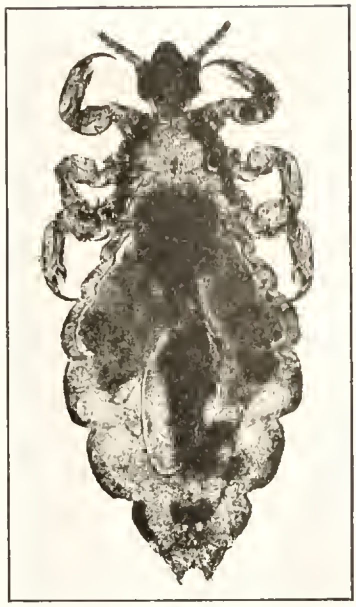
Typhus fever is most prone to occur in jails, ships, armies, and among the poor. It is often spoken of as a disease of filth. Filth and dirt

have nothing to do with it *per se,* any more than crowding. Filthiness and crowding are simply the conditions under which lice are most likely to be present, and most readily disseminated.

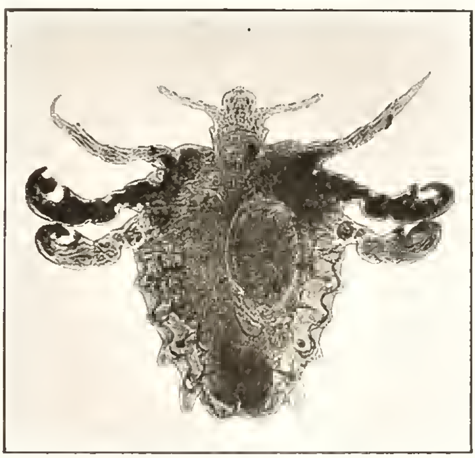
Among cleanly persons the disease is rare because they have no lice, and take care not to get them. The difficulty of preventing the disease is in direct proportion to the extent of lousiness among the population.

Delousing an individual is a comparatively simple matter that is successfully accomplished every day in our hospitals. The hair is treated with a decoction of Cocculus indicus, or some other satisfactory *insecticide,* the patient is bathed, and his clothing passed through a sterilizer whose heat kills both the adult lice and the eggs. But delousing a population presents almost insuperable difficulties. So soon as the free individual returns to association with his lousy fellows, or again sleeps in his customary haunts, he gathers up new vermin. It is a case of treating all or none, and keeping the treated apart until all are treated, including the clothing, the bedding, and the personal articles. It may even include animals. This cannot be achieved except through hearty co-operation or under vigorous military authority.

Head louse.



Body louse.



Crab louse.

Fig. 37.—The three varieties of human lice, any or all of which may transmit the micro-organisms of typhus fever. (From photographs by *Dr. F. D. Weidman.*)

RELAPSING FEVER.

This disease is caused by a minute spiral micro-organism first seen and described by Obermeier in

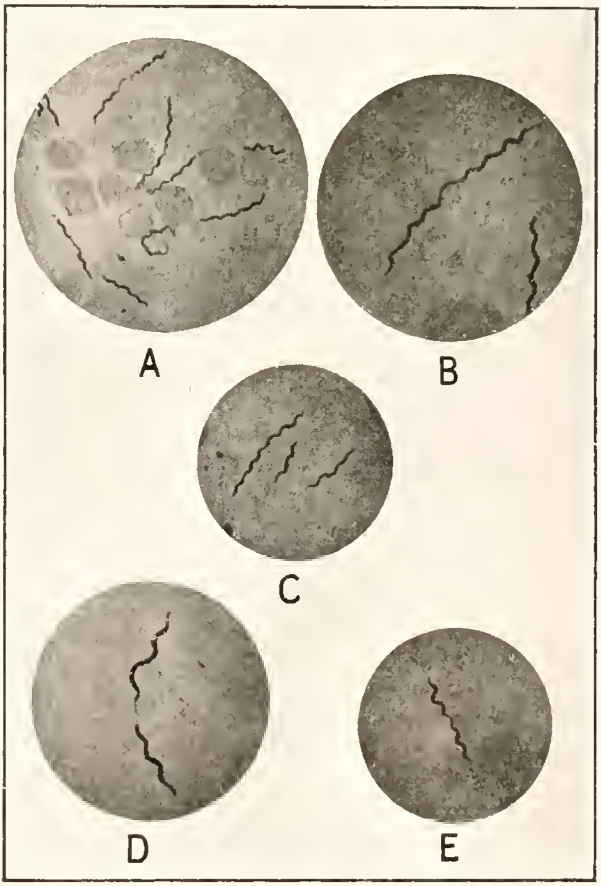
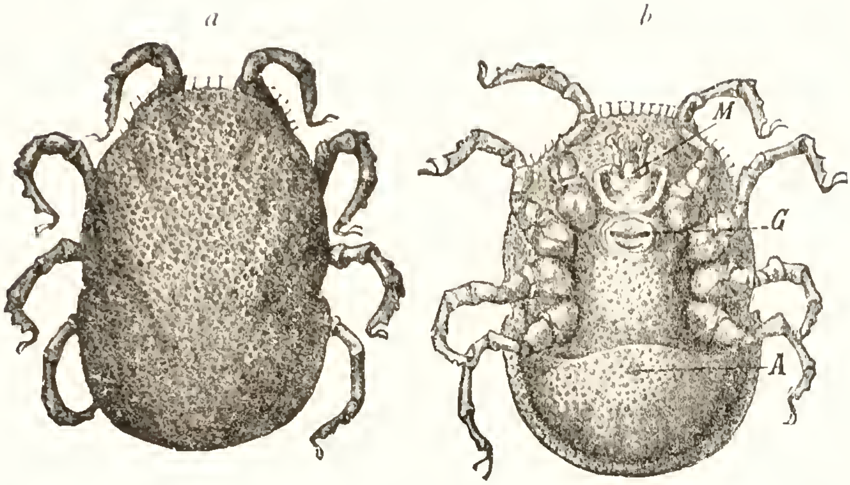
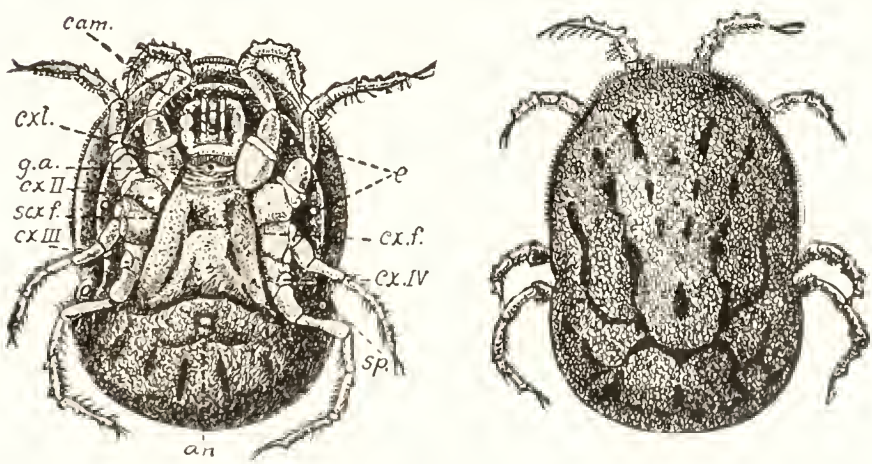


Fig. 38.—Spirochete of relapsing fever. The delicate screw-like objects are the micro-organisms magnified about 1000 diameters. (*Novy* and *Knapp.*)

1868. It is long, very slender, spirally curved like a corkscrew, and scarcely visible as it swims actively in the blood among its red corpuscles. Similar but



Ornithodorus moubata. *a*, Viewed from above; *b*, viewed from below.



Ornithodorus savignyi. *An*, anus; *cam*, camerostome; *cx.I*, coxa I; *cx.II*, coxa II; *cx.III*, coxa III; *cx.IV*, coxa IV; *cx.f.*, coxal fold; *e*, eyo; *g.a.*, genital aperture; *g.g.*, genital groove.

Fig. 39.—Ticks that transmit African Relapsing Fever.
(*Murray from Doflein.*)

slightly differing micro-organisms cause the slightly different relapsing fevers of different countries. But in all of them the spirochæte, as the organism is now called, is transmitted by some arthropod. In the various countries different arthropods are concerned, and for the first time, we find quite different insects acting in the same rôle. Thus, for the African relapsing fever it is a tick, called *Ornithodorus moubata;* for the relapsing fever of the Barbary States it is a somewhat similar tick, *Ornithorus savignyi,* but may be a louse, or the native bedbug, while for the European and American relapsing fevers the transmitting agent is not settled, though the bedbug is suspected, and the louse partly incriminated.

The relapsing fever is characterized by attacks of fever alternating with afebrile periods in which the patient seems to have recovered. The interval without fever lasts only for about a week, however, then the fever relapses, and with each recurrence, the patient is apt to be left weaker than before. After a varying number of attacks according to the form of the disease, the patient either recovers or dies, the African form being the most severe and fatal. The micro-organisms are present in the blood only during the febrile period, hence that is the only time that the appropriate arthropod can

infect itself. In the body of the creature, tick, louse or bug, it is necessary for the micro-organism to undergo some further stage of development, or if that is not the case, to await sufficient multiplication and dissemination through the body to cause its saliva to be infectious. This takes a number of days. The eggs of the arthropods also become in-

Fig. 40.—Ornithodorus savignyi, twice natural size. (*Nuttall.*)

fected, and the young hatched from them are infectious for several generations.

As in the other diseases of the class under discussion, there is no danger to be feared from the patient, it all centers about the insects. To keep from being bitten by them is to escape infection.

The habits of lice and bedbugs are sufficiently well-known not to require further attention, but those of the Ornithorus tick are somewhat different. These creatures behave not unlike bedbugs in that they remain quiescent during the day, and sally out to feed at night. They do not hide in the

beds, however, but in the crannies of the earthen floors of the native African houses, and inns.

When Prof. Koch made his expedition into equatorial Africa for the purpose of studying the native diseases, and reached a neighborhood in which relapsing fever was common, he divided his force of natives into two groups, one of which was permitted to camp in the native villages as usual, and sleep in their houses, while the other was kept outside, and compelled to camp upon new ground. In all other respects they were similarly treated, and given the same privileges.

The former suffered severely from relapsing fever, the latter largely escaped it.

Dr. Creighton Wellman, in Benguella Land, found that perfect safety resulted from tarring the ropes of hammocks in which his men slept suspended in native houses. The fresh tar kept the ticks from the bed, and so saved the sleepers.

The prevention of relapsing fever is conducted along the lines already laid down for the diseases whose spread is the result of the bites of insects.

The insect pests are to be as nearly as possible exterminated, the ill are to be carefully defended from their attacks, and the well must not permit themselves to be bitten.

In parts of the world where there is only one implicated arthropod as in Africa, this is more easy than where ticks, lice and bedbugs all have to be dealt with. The disease ought not to be frequent among the careful and cleanly as contrasted with the opposite classes of society.

PREVENTING DISEASES COMMON TO MAN, INSECTS AND SOME OTHER ANIMAL.

PLAGUE.

The plague, black plague or bubonic plague is a pestilential disease that has mysteriously appeared from time to time and carried off great numbers of people in a very sudden and painful manner. Plague is one of the most terribly epidemic, painful, and fatal diseases the world has known, so that there may be profit in devoting unusual space to its consideration, in order that the reader may be able to compare the fruitless efforts to stay its progress in past times, when the means of transmission was not understood, with the success of the present generation by which it has been determined.

In reading the following pages, let it not be forgotten that only a few years ago this devastating disease, again ravaging the orient, reached most of the ports of Europe, and both the Atlantic and Pacific ports of our own country, but was prevented

from spreading, and entirely extinguished, through the application of measures entirely different from those by which other epidemic diseases are combatted, and based upon precise knowledge of the cause of the disease and the means of its transmission.

In their "Anomalies and Curiosities of Medicine" Gould and Pyle give the following collection of general facts about the plague:

The Black Death, or as it has been known, the Oriental plague, the bubonic plague, or in England, simply the plague, and in Italy, "la Mortalega" (the great mortality), derived its name from the Orient: its inflammatory boils, tumors of the glands, and black spots, indicative of putrid decomposition, were such as have been seen in no other febrile disease. All the symptoms were not found in every case, and in many cases one symptom alone preceded death. Although afflicted with all the manifestations of the plague, some patients recovered. According to Hecker the symptoms of cephalic affliction were seen; many patients were stupified and fell into a deep sleep, or became speechless from palsy of the tongue, while others remained sleepless and without rest. The fauces and tongue were black and as if suffused with blood; no beverage could assuage the burning thirst, so that suffering continued without alleviation until death; which many in their despair accelerated with their own hands. Contagion was evident, for attendants caught the disease from their parents and friends, and many houses were emptied of their inhabitants. In the fourteenth century this affection caused still deeper sufferings such as had not been hitherto experienced. The organs of respiration became the seats of a putrid inflammation, blood was expectorated, and the breath possessed a pestiferous odor. In the west an ardent fever, accompanied

by an evacuation of blood, proved fatal in the first three days. It appears that bubos and inflammatory boils did not at first appear, but the disease in the form of carbuncular affection of the lungs (anthrax artigen) caused the fatal issue before the other symptoms developed. Later on in the history of the plague the inflammatory boils and bubos in the groins and axillæ were recognized at once as prognosticating a fatal issue.

The history of this plague extends almost to prehistoric times. There was a pest in Athens in the fifth century before Christ. There was another in the second century A.D., under the reign of Marcus Aurelius, and again in the third century, under the reign of the Gauls; following this was the terrible epidemic of the sixth century, which after having ravaged the territory of the Gauls, entended westward. In 542 a Greek historian, Procopius, born about the year 500, gives a good description of this plague in a work, "Pestilentia Gravissima," so called in the Latin translation. Dupouy in "*Le moyen age médical*," says that it commenced in the village of Peleuse, in Egypt, and followed a double course one branch going to Alexandria, and the other to Palestine. It reached Constantinople in the Spring of 543, and produced the greatest devastation wherever it appeared. In the course of the succeeding half century this epidemic became pandemic over all the inhabited earth. The epidemic lasted four months in Constantinople, from 5000 to 10,000 people dying each day. In his "History of France," from 417 to 591, Gregorius speaks of a malady under the name *inguinale* which depopulated the province of Arles. In another passage, this illustrious historian of Tours says that the town of Narbonne was devastated by a *maladie des aines.* We have records of epidemics in France from 567 to 590, in which bubonic symptoms were a prominent feature. About the middle of the fourteenth century, the bubonic plague made another incursion from the East. In 1333, fifteen years before the plague appeared in

Europe, there were terrible droughts in China followed by enormous floods in which thousands of people perished. There are traditions of a plague in Tche in 1334, following a drought, which is said to have carried off about 5,000,000 people. During the fifteen years before the appearance of the plague in Europe, there were peculiar atmospheric phenomena all over the world beside numerous earthquakes. From the description of the stinking atmosphere of Europe itself at this time, it is quite possible that part of the disease came not from China, but originated in Southern Europe itself. From China the route of caravans ran to the north of the Caspian Sea, through Asia to Tauris. Here ships were ready to take the produce of the East to Constantinople, the capital of commerce, and the medium of communication between Europe, Asia and Africa. Other caravans went from Europe to Asia Minor and touched at the cities south of the Caspian Sea, and lastly there were others from Bagdad, through Arabia to Egypt; the maratime communication on the Red Sea to Arabia and Egypt was also not inconsiderable. In all these directions contagion found its way, though doubtless Constantinople and the harbors of Asia Minor were the chief foci of infection, whence it radiated to the most distant sea-ports and islands. As early as 1347 the Mediterranean shores were visited by the plague, and in January, 1348, it appeared in the south of France, the north of Italy, and also in Spain. Place after place was attacked throughout the year, and after ravishing the whole of France and Germany, the plague appeared in England, a period of three months elapsing before it reached London. The northern kingdoms were attacked in 1349, but in Russia it did not make its appearance before 1351.

As to the mortality of this fearful epidemic Dupouy considers that in the space of four years more than 75,000,000 people fell victims, that is about half of the population of the countries visited. Hecker estimates that from 1347 to

1351, 25,000,000 people died, or one-quarter of the total population of Europe. It was reported to Pope Clement that throughout the East, probably with the exception of China, nearly 24,000,000 people had fallen victims to the plague. Thirteen millions are said to have died in China alone. Constantinople lost two-thirds of its population. When the plague was at its greatest violence Cairo lost daily from 10,000 to 15,000, as many as modern plagues have carried off during their whole course. India was depopulated. Tartary, Mesopotamia, Syria, Armenia, and Arabia were covered with dead bodies. . . . The shores of the Mediterranean were ravaged and ships were seen on the high seas without sailors. In "The Decameron" Boccaccio gives a most graphic description of the plague, and states that in Florence, in four months, 100,000 perished; before the calamity it was hardly supposed to contain so many inhabitants. According to Hecker, Venice lost 100,000; London, 100,000; Paris, 50,000; Vienna, 70,000; Avignon, 60,000; Strasburg, 16,000; Norwich, 51,000. Dupouy says that in one month there were 56,000 victims in Marseilles, and at Montpellier three-fourths of the population and all of the physicians were stricken with the epidemic.

Johanna of Burgundy, wife of King Philip VI, of Valois; Johanna II, Queen of Navarre, grand-daughter of Philippe le bel; Alphonse XI, of Castile, and other notable persons perished. Germany seems to have been particularly spared; according to a probable calculation, only about 1,250,000 dying. Italy was most severely visited, and was said to have lost most of its inhabitants. In the north of Europe, two of the brothers of Magnus, King of Sweden, died; and in West Gothland alone, 466 priests died. The plague showed no decrease in the northern climates of Iceland and Greenland, and caused great havoc in those countries.

Accounts of the plague fill many pages of the world's literature, but I know of none better than

that given by Bocaccio in his introduction to the "Decameron:"

In the year of our Lord 1348, there happened at Florence, the finest city in all Italy, a most terrible plague: which whether owing to the influence of the planets, or that it was sent from God as a just punishment for our sins, had broken out some years before in the Levant, and after passing from place to place, and making incredible havock all the way, had now reached the west.

There, spite all the means that art and human foresight could suggest, such as keeping the city clean from filth, the exclusion of all suspected persons, and the publication of copious instructions for the preservation of health; and notwithstanding manifold humble supplications offered unto God in processions and otherwise, it began to show itself in the spring of the aforesaid year, in a sad and wonderful manner. Unlike what had been seen in the east, where bleeding from the nose is the fatal prognostic, here there appeared certain tumors in the groin or under the armpits, some as big as a small apple, others as an egg, and afterward purple spots in most parts of the body; in some cases large and but few in number, in others smaller and more numerous—both sorts the usual messengers of death. To the cure of this malady, neither medical knowledge nor the power of drugs was of any effect; whether the disease was in its own nature mortal, or that the physicians (the number of whom, taking quacks and women pretenders into account, was grown very large) could form no just idea of the cause, nor consequently devise a true method of cure: which ever was the reason, few escaped; but nearly all died the third day from the appearance of the symptoms, some sooner, some later, without any fever or accessory symptoms.

What gave the more virulence to this plague, was that, being communicated from the sick to the hale, it spread

daily, like fire when it comes in contact with large masses of combustibles. Nor was it caught only by conversing with, or coming near the sick, but even by touching their clothes, or anything that they had before touched. It is wonderful what I am going to mention, and had I not seen it with my own eyes, and were there not many witnesses to attest it besides myself, I should never venture to relate it, however worthy it were of belief. Such I say was the quality of the pestilential matter, as to pass not only from man to man, but, what is more strange, it has been often known, that anything belonging to the infected, if touched by any other creature, would certainly infect, and even kill the creature in a short time. One instance of this kind I took particular notice of; the rags of a poor man just dead had been thrown into the street; two hogs came up, and after rooting among the rags, and shaking them about in their mouths, in less than an hour they both turned round, and died on the spot. . . .

I pass over the little regard that citizens and relations showed to each other; for their terror was such that a brother even fled from his brother, a wife from her husband, and, what is more common, a parent from his own child. Hence numbers that fell sick could have no help but what the charity of friends, who were very few, or the avarice of servants supplied; and even these were scarce and at extravagant wages, and so little used to the business that they were fit only to reach what was called for, and observe when their employer died; and this desire of getting money often cost them their lives. . . . So that between the scarcity of servants and the violence of the distemper, such numbers were continually dying, as made it terrible to hear as well as to behold. Whence from mere necessity many customs were introduced different from what had before been known in the city.

It had been usual, as it is now, for women who were friends and neighbors to the deceased, to meet together at

his house, and to lament together with his relations; at the same time the men would get together at the door with a number of the clergy, according to the person's circumstances; and the corpse was carried by his own rank, with the solemnity of tapers and singing, to that church where the deceased had desired to be buried. This custom was now laid aside, and, so far from having a crowd of women to lament over them, great numbers passed out of the world without a witness. For they were very few who had the tears of their friends at their departure; those friends were laughing and making merry the while; for even the women had learned to postpone every other concern to that of their own lives. Nor was a corpse attended by more than ten or a dozen, nor those citizens of credit, but fellows hired for the purpose; who would put themselves under the bier, and carry it with all possible haste to the nearest church; and the corpse was interred, without any great ceremony where they could find room. With regard to the lower sort, and many of a middling rank, the scene was still more affecting; for they staying at home either through poverty or hopes of succor in distress, fell sick daily by the thousands, and, having nobody to attend them, generally died; some breathed their last in the streets, and others shut up in their own houses, where the stench that came from them made the first discovery of their deaths to the neighborhood. And indeed every place was filled with dead. Hence it became a general practice, as well out of regard for the living as pity for the dead, for the neighbors, assisted by what porters they could meet with, to clear all the houses, and lay the bodies at the doors; and every morning great numbers might be seen brought out in this manner, to be carried away on biers, or tables two or three at a time; and sometime it has happened that a wife and her husband, two or three brothers, and a father and a son have been laid on

together. It has been observed also that while two or three priests have walked before a corpse with their crucifix, two or three sets of porters have fallen in with them; and where they knew of but one dead body, they have buried six, eight or more: nor was there any to follow and shed a few tears over them; for things were come to that pass, that men's lives were no more regarded than the lives of so many beasts. Thus it plainly appeared, that what the wisest in the ordinary course of things, and by a common train of calamities, could never be taught, namely to bear them patiently, this by the excess of the calamity, was now grown a familiar lesson to the most simple and unthinking.

The consecrated ground now no longer containing the numbers continually brought thither, especially as they were very desirous of laying every one in the part allotted to their families, they were forced to dig trenches, and to put them in by hundreds, piling them up in rows, as goods are stowed in a ship, and throwing in a little earth till they were filled to the top.

Not to dwell upon every particular of our misery, I shall observe that it fared no better with the surrounding country; for to omit the different boroughs about us, which presented the same view in miniature with the city, you might see the poor distressed laborers, with their families, without either the aid of physician or help of servants, languishing on the highways, in the fields, and in their own houses, and dying rather like cattle than like human creatures. . . .

What can I say more if I return to the city? unless that such was the cruelty of Heaven and perhaps of men, that between March and July following, according to the most authentic reckonings, upward of a hundred thousand souls perished in the city only whereas, before that calamity, it was not supposed to have contained so many inhabitants.

In the diary of Samuel Pepys, running through that part of it between April 30th, 1665 and January 30th, 1666, can be found an account of the great plague of London. If one collects the scattered paragraphs, he finds the following interesting sketch of the progress of the epidemic:

April 30th, 1665. Great fears of the sicknesse here in the city, it being said that two or three houses are already shut up. God preserve us all!

May 28th. But my poor Lady [Lady Sandwich] who is afraid of the sickness, and resolved to be gone into the country, is forced to stay in town a day or two, or three, . . .

June 7th. This day, much against my will, I did in Drury Lane see two or three houses marked with a red cross upon the doors, and "Lord have mercy upon us!" writ there: which was a sad sight to me, being the first of the kind that, to my remembrance, I ever saw.

June 10th. In the evening home to supper; and thereto my great trouble, hear that the plague is coming into the City, though it hath, these three or four weeks, since its beginning, been wholly out of the City: but where should it begin but in my good friend and neighbor's Dr. Burnett, in Fenchurch Street: which in both points troubles me mightily.

June 15th. The town grows very sickly, and people to be afraid of it: there dying, this last week, of the plague 112, from 43, the week before; whereof but one in Fenchurch Streete, and one in Broad Streete by the Treasurer's office.

June 20th. This day I informed myself that there died four or five at Westminister of the plague, in several houses,

upon Sunday last, in Bell Alley, over against the Palace gate; yet people do think that the number will be fewer in the town than it was last week.

June 22nd. In great pain whether to send my mother into the country to-day or no; I hearing, by my people, that the poor wretch hath a mind to stay a little longer, and I cannot blame her. At last, I resolved to put it to her, and she agreed to go, because of the sickness in the town, and my intentions of removing my wife. She was to the last unwilling to go, but would not say so, but put it off till she lost her place in the coach, and was fain to ride in the waggon part.

June 23rd. Home by a hackney coach, which is becomming a very dangerous passage now-a-days, the sickness increasing mightily.

June 27th. The plague increases mightily, I this day seeing a house, at a bitt-maker's, over against St. Clement's Church, in the open street, shut up; which is a sad sight.

June 29th. By water to White Hall, where the Court is full of waggons and people ready to go out of town. This end of the town every day grows very bad of the plague. The mortality bill is come to 267; which is about 90 more than the last: and of these but four in the City, which is a great blessing to us. Took leave of Mr. Coventry; though I hope the Duke is not gone to stay, and so do others too.

July 1st. To Westminister, where I hear the sickness encreases greatly. Sad at the news, that seven or eight houses in Burying Hall Street are shut up of the plague.

July 3rd. The season grows so sickly, that it is much to be feared how a man can escape having a share with others in it, for which the Good Lord bless me! or make me fitted to receive it.

July 5th. Advised about sending my wife's bedding and things to-day to Woolwich, in order to her removal thither. Walked round to White Hall, the Park being quite locked up; and I observed a house shut up this day in the Pell Mell, where, heretofore in Cromwell's time, we young men used to keep our weekly clubs.

July 6th. I could not see Lord Brouncker, nor had much mind to, one of the two great houses within two doors of him being shut up; and, Lord! the number of houses visited, which this day I observed through the town, quite round in my way, by Long Lane and London Wall.

July 10th. It is, I perceive, an unpleasant thing to be at the Court, every body being fearful one of another, and all so sad enquiring after the plague, so that I stole away by my horse to Kingston. . . .

July 12th. After doing what business I could in the morning, it being a solemn fast day for the plague growing upon us, I took boat, and down to Deptford. . . .

July 13th. Above 700 died of the plague this week.

July 18th. I was much troubled this day to hear, at Westminister, how the officers do bury the dead in the open Tuttle-fields, pretending want of room elsewhere; whereas the new chapel churchyard was walled in at the publick charge in the last plague-time, merely for want of room; and now none, but such as are able to pay dear for it, can be buried there.

July 20th. Walked to Redriffe, where I hear the sickness is, and, indeed is scattered almost everywhere, there dying 1089 of the plague this week. My Lady Carteret did this day give me a bottle of plague water home with me . . . Lord! to see how the plague spread! it being now all over King Streete, at the Axe, and next door to it, and in other places.

July 22. . . . a poor woman came to scold with the master of the house that a kinswoman, I think, of her's, that was nearly dead of the plague, might be buried in the churchyard; for for her part, she should not be buried in the commons, as they said she should. I came home by coach, not meeting with but two coaches and but two carts from White Hall to my own house, that I could observe, and the streets mighty thin of people. I met this noon with Dr. Burnett, who told me, and I find in the news-book, this week that he posted upon the 'Change, that whoever did spread the report that, instead of dying of the plague, his servant was by him killed, it was a forgery, and showed me the acknowledgment of the Master of the pest-house, that his servant died of a bubo on the right groine and two spots on his right thigh, which is the plague.

July 25th. Sad the story of the plague in the City, it grows mightily.

July 26th. Sad news of the death of so many in the parish of the plague, 40 last night. The bells are always going. . . . This day poor Robin Shaw at Bakewell's died, and Bakewell himself now in Flanders. The King himself asked about Shaw, and being told he was dead, he said he was very sorry for it. The sickness is got into our parrish this week, and is got, indeed, everywhere; so that I begin to think of setting things in order, which I pray God enable me to put, both as to soul and body.

July 27th. At home met the weekly Bill, where above 100 encreased in the Bill; and all of them, in all, about 1700 of the plague, which hath made the officers this day resolve of sitting at Deptford, which puts me to some consideration what to do.

July 28th. But, Lord! to see in what fear the people here [Dagenhams] do live. How they are afraid of us that come to them, insomuch that I am troubled at it, and wish myself away. But some cause they have; for the chaplain, with whom, but a week or two ago, we were here mighty high disputing, is since fallen into a fever, and dead, being gone hence to a friend's a good way off. A sober and healthful man.

July 30th. It is a sad noise to hear our bell to toll and ring so often today either for deaths or burials; I think five or six times.

July 31st. Proctor, the vintner, of the Miter, in Wood Street, and his son, are dead this morning there, of the plague.

. . . because of the plague, which grows mightily upon us, the last week being about 1700 or 1800 of the plague.

August 1st. . . . a public fast, as being the first Wednesday of the month for the plague; within doors all day. . . .

August 3rd. . . . and so to the ferry, where I was forced to stay a great while before I could get my horse brought over, and then mounted and rode very finely to Dagenhams; all the way, people, citizens, walking too and fro, enquire how the plague is in the city this week by the Bill; which by chance at Greenwich, I had heard was 2020 of the plague, and 3000 and odd, of all diseases; but methought it was a sad question to be so often asked me.

. . . a maid servant of Mr. John Wright's, who lives thereabouts, falling sick of the plague, she was removed to an outhouse, and a nurse appointed to look after her; who, being once absent, the maid got out of the window and ran away. The nurse coming and knock-

ing, and having no answer, believed she was dead, and went and told Mr. Wright so; who and his lady were in a great straight what to do to get her buried. At last resolved to go to Burntwood, hard by being in the parish, and there get people to do it. But they would not: so he went home full of trouble, and in the way met the wench walking over the common, which frightened him worse than before; and was forced to send people to take her, which he did; and they got one of the pest-coaches, and put her into it to carry it to the pest-house. And in passing in a narrow lane, Sir Anthony Browne, with his brother and some friends in the coach, met this coach with the curtains drawn close. The brother being a young man, and believing there might be some lady in it that would not be seen, and the way being very narrow, he thrust his head out of his own into her coach, and to look, and there saw somebody looking very ill, and in a silk dress, and stunk mightily: which the coachman also cried out upon. And presently they came up to some people that stood looking after it, and told our gallants that it was a maid of Mr. Wright's carried away sick of the plague, which put the young gentleman into a fright had almost cost him his life, but is now well again.

August 8th. To my office a little, and then to the Duke of Albemarl's about some business. The streets are empty all the way, now, even in London, which is a sad sight. And to Westminister Hall, where, talking, hearing very sad stories from Mrs. Mumford; among others, of Mr. Mitchell's son's family. And poor Will, that used to sell us ale at the Hall-door, his wife and three children died all, I think in a day. So home, through the City again, wishing I may have taken no ill in going; but I will go, I think, no more thither.

. . . By and by to the office, where we sat all the morning; in great trouble to see the Bill this week rise so high, to above 4000 in all, and of them above 3000 of the plague. Home to draw over anew my will which I had bound myself by oath to dispatch by tomorrow night; the town growing so unhealthy, that a man cannot depend upon living two days.

August 11th. Setting my house and all things in the best order I can, lest it should please God to take me away, or force me to leave my house.

August 12th. The people die so, that it now seems they are fain to carry the dead to be buried by daylight, the nights not sufficing to do it in. And my Lord Mayor commands people to be within at nine at night all, as they say, that the sick may have liberty to be abroad for ayre. There is one also dead out of our ships at Deptford, which troubles us mightily. . . .

August 15th. It was dark before I could get home, and so land at Churchyard stairs, where to my great trouble, I met a dead corpse of the plague, in the narrow alley, just bringing down a little pair of stairs. But I thank God I was not much disturbed at it. However, I shall be aware of being late abroad again.

August 16th. To the Exchange, where I have not been a great while. But Lord! how sad a sight it is to see the streets empty of people, and very few upon the 'Change! Jealous of every door that one sees shut up, lest it should be the plague; and about us two shops in three, if not more generally shut up.

August 18th. Late in the dark to Gravesend, where great is the plague, and I troubled to stay there so long for the tide.

August 20th. Mr. Povy not being at home, I lost my labor —only eat and drank there with his lady, and told my

bad news, and hear the plague is round about them there . . . and I could not get my waterman to go elsewhere, for fear of the plague. Thence with a lanthorn, in great fear of meeting of dead corpses, carrying to be buried; but, blessed be God! met none, but did see, now and then a link, which is the mark of them at a distance.

August 21st. Messengers went to get a boat for me, to carry me to Woolwich, but all to no purpose: so I was forced to walk it in the dark, at ten o'clock, with Sir J. Minne's George with me, being mightily troubled for fear of the doggs at the Coome farme, and more for fear of rogues by the way, and yet more of the plague which is there which is very strange, it being a single house, all alone from the town, but it seems that they used to admit beggars, for their own safety, to lie in their barns, and they brought it to them. . . . I went away, and walked to Greenwich, in my way seeing a coffin with a dead body therein, dead of the plague, lying in an open close belonging to Coome farm, which was carried out last night, and the parish have not appointed any body to bury it; but only set a watch there day and night, that nobody should go thither or come thence: this disease making us more cruel to one another than we are to dogs.

Walked to Redriffe, troubled to go through the little lane where the plague is, but did, and took water and home, where all well.

August 25th. I am told that Dr. Burnett, my physician, is this morning dead of the plague; which is strange, his man dying so long ago, and his house this month open again. Now, himself dead! Poor unfortunate man!

August 26th. . . . By water home, in my way seeing a man taken up dead, out of the hold of a small catch

that lay at Deptford. I doubt it might be the plague, which, with the thought of Dr. Burnett, did something disturb me. So home sooner than ordinary, and, after supper, to read melancholy and alone, and then to bed.

August 28th. To the Exchange, and there was not fifty people upon it, and but few more like to be, as they told me. I think, to take adieu today of the London streets.

August 30th. Abroad, and met with Hadley, our clerk, who, upon my asking him, how the plague goes, told me it encreases much, and much in our parish; for, says he, there died nine this week, though I have returned but six: which is a very ill practice, and makes me think it is so in other places; and therefore the plague much greater than people take it to be. I went forth, and walked towards Moorfields to see, God forgive my presumption! whether I could see any dead corpse going to the grave; but as God would have it, I did not. But Lord! how every body's looks, and discourse in the street is of death, and nothing else; and few people going up and down, that the town is like a place distressed and forsaken.

August 31. Up; and after putting several things in order to my removal, to Woolwich; the plague having a great encrease this week, beyond all expectation, of almost 2000, making the general Bill 7000 odd 100; and the plague above 6000. Thus this month ends with great sadness to the publick, through the greatness of the plague everywhere through the kingdom almost. Every day sadder and sadder news of its encrease. In the City died this week 7496, and of them 6102 of the plague. But it is feared that the true number of the dead, this week is near 10,000: partly from the poor that cannot be taken notice of, through the greatness

of the number, and partly from the Quakers and others that will not have any bell to ring for them. . . . As to myself, I am very well, only in fear of the plague, and as much of an ague, by being forced to go early and late to Woolwich, and my family to lie there continually.

September 3rd. . . . my new perriwigg, bought a good while since, but durst not ware, because the plague was in Westminister when I bought it; and it is a wonder what will be the faehion after the plague is done; as the perriwiggs, for nobody will dare to buy any haire, for fear of the infection, that it had been cut off the heads of people dead of the plague. . . . But Lord! to consider the madness of the people of the town, who will, because they are forbid, come in crowds along with the dead corpses to see them buried; but we agreed on some orders for the prevention thereof. Among other stories was one very passionate, methought, of a complaint against a man in the town, for taking a child from London from an infected house. Alderman Hooker told us that it was the child of a very able citizen in Gracious Street, a saddler, who had buried all the rest of his children of the plague, and himself and wife now being shut up in despair of escaping, did desire only to save the life of this little child; and so prevailed to have it received stark naked into the arms of a friend, who brought it, having put it into new fresh clothes, to Greenwich; where, upon hearing the story, we did agree it should be permitted to be received and kept in the town.

September 4th. Walked home, my Lord Brouncker giving me a very neat cane to walk with; but it troubled me to pass by Coome farm, where about twenty-one people have died of the plague.

September 6th. To London to pack up more things; and there I saw fires burning in the street, as it is through the whole city, by the Lord Mayor's order. Thence by water to the Duke of Albemarl's: all the way fires on each side of the Thames, and strange to see in broad daylight two or three burials upon the bankside, one at the very heels of another; doubtless all of the plague; and yet at least forty or fifty people going along with every one of them.

September 7th. To the Tower, and there sent for the Weekly Bill, and find 8252 dead in all, and of them 6978 of the plague; which is a most dreadful number, and shows reason to fear that the plague hath got that hold that it will yet continue among us.

September 10th. My wife . . . telling me the ill news that she hears, that her father is very ill, and then I told her that I feared of the plague, for that the house is shut up.

September 14th. . . . there being now no observation of shutting up houses infected . . . we do converse and meet people that have the plague upon them . . . the decrease of 500 or more, which is the first decrease we have had in the sickness since it began: and great hopes that next week it will be greater. Then, on the other side, my finding that though the Bill in general is abated, yet the City within the walls is encreased, and likely to continue so, and is close to our house there. My meeting dead corpses of the plague, carried to be buried close to me at noon-day through the City in Fenchurch Street. To see a man sick of the sores carried close by me by Grace Church in a hackney-coach. My finding the Angel tavern, at the lower end of Tower Hill, shut up; and more than that, the ale-house at the Tower Stairs; and more than that, that the

person was then dying of the plague when I was last there, a little while ago at night. To hear that poor Payne, my waiter hath buried a child and is dying himself. To hear that a laborer I sent but the other day to Dagenhams, to know how they did there, is dead of the plague; and that one of my own watermen, that carried me daily, fell sick as soon as he had landed me on Friday morning last, when I had been all night upon the water, and I believe he did get his infection that day at Branford, and is now dead of the plague. To hear . . . that Mr. Sidney Montague is sick of a desperate fever at my Lady Cartaret's, at Scott's Hall. To hear that Mr. Lewes hath another daughter sick. And lastly, that both my servants, W. Hewer, and Tom Edwards, have lost their fathers, both in St. Sepulchre's parish, of the plague, this week, do put me into great apprehensions of melancholy, and with good reason. But I put off my thoughts of sadness as much as I can, and the rather to keep my wife in good heart, and the family also.

September 19th. . . . But Lord! what a sad time it is to see no boats upon the river; and grass grows all up and down the White Hall court, and nobody but poor wretches in the streets! And, which is worst of all, the Duke showed us the number of the plague this week, brought in last night from the Lord Mayor; and it is encreased about 600 more than the last, which is quite contrary to our hopes and expectations, from the coldness of the late season. For the whole general number is 8297, and of them, the plague 7165; which is more in the whole, by above 50 than the biggest Bill yet; which is very grievous to us all. I find Sir W. Batten and his lady gone home to Walthamstow, and with some necessity, hearing that a maid servant of their's is taken ill.

September 21st. Up between five and six o'clock; and by the time I was ready, Lord Broenker's coach comes for me; and, taking Will Hewer with me, who is all in mourning for his father, who is lately dead of the plague, as my boy Tom's is also, I set out. . . .

September 27th. . . . I saw this week's Bill of Mortality, wherein, blessed be God! there is above 1800 decrease, being the first considerable decrease we have had.

September 29th. Sir Martin Noell is this day dead of the plague, in London, where he hath lain sick of it these eight days.

October 3rd. This night, I hear that, of our two watermen that used to carry our letters, and were well on Saturday last, one is dead, and the other dying of the plague; the plague, though decreasing elsewhere, yet being greater about the Tower and thereabouts.

October 4th. This night comes Sir George Smith to see me at the office, and tells me how the plague is decreased this week 750, for which God be praised! but that it encreases at our end of the town still.

October 7th. . . . Talking with him in the highway, come close by the bearers with a dead corpse of the plague; but Lord! that I am come almost to think nothing of it.

October 16th. I walked to the Tower; but, Lord! how empty the streets are, and melancholy, so many poor, sick people in the streets full of sores; and so many sad stories overheard as I walk, everybody talking of this dead, and that man sick, and so many in this place, and so many in that. And they tell me that, in Westminister, there is never a physician and but one apothecary left, all being dead; but that there are great hopes of a great decrease this week: God send it!

October 26. . . . The 'Change pretty full, and the town begins to be lively again, though the streets very empty, and most shops shut.

October 29th. (Lord's Day). In the street at Woolwich, did overtake and almost run upon two women crying and carrying a man's coffin between them; I suppose the husband of one of them, which, methinks, is a sad thing.

October 31st. . . . Thus we end the month merrily; and the more that, after some fears that the plague would have increased again this week I hear for certain that there are above 400 less; the whole number of deaths being 1388, and them of the plague 1031.

November 4th. I hear that one of the little boys at my lodging is not well; and they suspect, by their sending for plaister and fume, that it may be the plague; so I sent Mr. Hater and W. Hewer to speak with their mother; but they returned to me, satisfied that there was no hurt nor danger, but the boy is well, and offers to be searched.

November 8th. It being a fast day, all people were at church, and the office was quiet; so I did much business, and at noon adventured to my old lodging. By water to Deptford, and about eight o'clock at night, did take water, being glad I was out of the town; for the plague, it seems, rages there more than ever.

November 9th. . . . The Bill of Mortality, to all our griefs, is encreased 399 this week, and the encrease generally through the whole City and suburbs, which makes us all sad.

November 12th. They hope here the plague will be less this week.

November 14th. Captain Cocke and I in his coach through Kent Streete, a sad place through the plague, people sitting sick and with plaisters about them in the street begging. . . . This day I hear that my pretty grocer's wife, Mrs. Beverham, over the way, there, her husband is lately dead of the plague at Bow, which I am sorry for, for fear of losing her neighborhood.

November 15th. The plague, blessed be God! is decreased 400; making the whole, this week about 1300 and odd: for which the Lord be praised!

November 20th. . . . Here I find Mr. Deering come to trouble me about business, which I soon dispatched, he telling me that Luellin hath been dead this fortnight, of the plague, in St. Martin's Lane, which much surprised me.

November 22nd. I was very glad to hear that the plague is come very low; that is, the whole under 1000, and the plague 600 and odd: and great hopes of a further decrease, because of this day's being an exceeding hard frost, and continues freezing.

November 23rd. . . . It continuing to be a great frost, which gives us hopes for a perfect cure of the plague, he and I to walk in the park, and there discoursed with grief of the calamity of the times.

November 26th. (Lord's Day). . . . To my wife at Woolwich, where I found, as I had directed, a good dinner to be made against tomorrow, and invited guests in the yard, meaning to be merry, in order to her taking leave, for she intends to come in a day or two to me for altogether. But here, they tell me, one of the houses behind them is infected, and I was fain to stand there a great while, to have their backdoors opened, but they could not, having locked them fast, against any passing through, so was forced to pass by them again, close to

their sick beds, which they were removing out of the house, which troubled me: so I made them uninvited guests, and to resolve of coming all away to me tomorrow.

November 28th. Took boat and down to Greenwich. Cocke home, and I to the office, and then to my lodgings, where my wife is come, and I am well pleased with it, only much trouble in those lodgings we have the mistress of the house being so deadly dear in everything we have so that we do resolve to remove home as soon as we know how the plague goes this week, which we hope will be a good decrease.

November 30th. . . . Great joy we have this week in the weekly Bill, it being come to 544 in all, and but 333 of the plague; so we are encouraged to get to London as soon as we can. And my father writes as great news of joy to them, that he saw York's waggon go again this week to London, and full of passengers; and tells me that my aunt Bell hath been dead of the plague these seven weeks.

December 4th. Home to my house at the office, where my wife hath got a dinner for me; and it was a joyful thing for us to meet here, for which God be praised!

December 13th. . . . though my great trouble is that my poor little parish is the greatest number this week in all the city within the walls, having six from one the last week, . . .

Away to the 'Change and there hear the ill news, and to my great, and all our trouble, that the plague is encreased again this week, notwithstanding that there have been a long day or two of great frosts; but we hope it is only the effects of the late close warm weather, and if the frost continue the next week, may fall again: but the town do thicken so much with

people, that it is much if the plague do not grow again upon us.

December 22nd. The weather hath been frosty these eight or nine days, and so we hope for an abatement of the plague the next week, or else God have mercy upon us! for the plague will certainly continue for the next year, if it do not.

December 27th. Home to my wife, and angry about her desiring a maid yet, before the plague is quite over.

December 31st. My whole family hath been well all this while, and all my friends I know of, saving my aunt Bell, who is dead, and some children of my cousin Sarah's, of the plague. But many of such as I know well, dead: yet, to our great joy, the town fills apace, and shops begin to be open again. Pray God continue the plague's decrease! for that keeps the court away from the place of business, and so all goes to rack as to public matters, they at this distance not thinking of it.

January 3rd, 1666. I to the Duke of Albemarl's and back again: and, at the Duke's, with great joy received the good news of the decrease of the plague this week to 70, and but 253 in all; which is the least Bill that hath been known these twenty years in the City. . . .

January 5th. And how delightful it is to see the town full of people again: and shops begin to open, though in many places seven or eight together, and more all shut: but yet the town is full, compared with what it used to be. I mean the City end; for Covent Garden and Westminister are yet very empty of people, no court nor gentry being there.

January 16th. Mightily troubled at the news of the plague's being encreased, and was much the saddest news that the plague hath brought me from the beginning of it:

because of the lateness of the year, and the fear we may with reason have of its continuing with us next summer. The total being now 375, and the plague 158.

January 22nd. The first meeting of Gresham College since the plague. Dr. Goddard did fill us with talk, in defence of his and his fellows going out of town in the plague-time: saying that their particular patients were most gone out of town, and they left at liberty and a great deal more.

January 23rd. Good news beyond all expectation of the decrease of the plague, being now but 79, and the whole but 272.

January 30th. Home, finding the town keeping the day solemnly, it being the day of the King's murther; and they being at church, I presently into the church. This is the first time I have been in the church since I left London for the plague, and it frightened me to go through the church more than I thought it could have done, to see so many graves lie so high upon the churchyards, where people have been buried of the plague.

February 2nd. . . . To White Hall, and to my great joy, people begin to bustle up and down there, the King holding his resolution to be in town tomorrow, and hath good encouragement, blessed be God! to do so, the plague being decreased this week to 56, and the total to 227.

February 13th. Ill news this night, that the plague is encreased this week, and in many places else about the town, and at Chatham and elsewhere.

February 22nd. We are much troubled that the sickness in general, the town being so full of people, should be but three, and yet of the particular disease of the plague there should be ten encrease.

March 1st. Blessed be God! a good Bill this week we have; being but 237 in all, and 42 of the plague, and of them but six in the City; though my Lord Brouncker says that these six are most of them in new parishes, where they were not last week.

March 13th. The plague encreased this week 29 from 28, although the total fallen from 238 to 207.

April 5th. . . . The plague is, to our great grief, encreased nine this week, though decreased a few in the total. An this encrease runs throu many parishes, which makes us much fear the next year.

April 23rd. . . . The plague, I hear, encreases in the town much, and exceedingly in the country everywhere.

April 25th. . . . The plague, blessed be God! is decreased 16 this week.

July 4th. . . . Thanks be to God! the plague is, I hear, increased but two this week; but in the country in several places, it rages mightily, and particularly in Colchester, where it hath long been, and is believed will quite depopulate the place.

August 6th. . . . In Fenchurch Street met with Mr. Battersby; he says, "Do you see Dan Rawlinson's door shut up?" which I did, and wondered "Why," says he, "after all this sickness, and himself spending all the last year in the country, one of his men is now dead of the plague, and his wife and one of his maids sick, and himself shut up;" which troubles me mightily.

August 10th. Homeward, and hear in Fenchurch Street, that now the maid is also dead at Mr. Rawlinson's; so that there are three dead in all, the wife, the man-servant, and the maid-servant.

On September 1st, the great fire broke out, and Pepy's further interest in the plague became lost.

John Evelyn, in his almost equally famous diary of the same period, makes more brief references to the epidemic, yet in much the same vein:

July 16th, 1665. There died of the plague, in London, this week 1100; and in the week following, above 2000. Two houses were shut up in our parish.

August 2nd. A solemn fast through England to deprecate God's displeasure against the land by pestilence and war: our Doctor preaching on 2 Levit.v.41,42, that the means to obtain remission of punishment was not to repine at it; but humbly to submit to it.

August 4th. I went to Wotton with my son and his tutor . . . for fear of the pestilence, still increasing in London and its environs.

August 15th. There perished this week 5000.

August 28th. The contagion still increasing, and growing now all about us, I sent my wife and whole family . . . to my brother's at Wotton being resolved to stay at the house myself, and to look after my charge, trusting in the providence and goodness of God.

September 7th. Came home, there perishing near 10,000 poor creatures weekly; however, I went all along the City and suburbs from Kent Street to St. James's, a dismal passage, and dangerous to see so many coffins exposed in the streets, now thin of people; the shops shut up, and all in mornful silence, not knowing whose turn it might be next.

October 11th. To London, and went through the whole City, having occasion to alight out of the coach in several places about business of money, when I was envir-

oned with multitudes of poor pestiferous creatures begging alms: the shops universally shut up, a dreadful prospect!

November 23rd. Went home, the contagion having now decreased considerably.

December 31st. Now blessed be God for His extraordinary mercies and preservation of me this year, when thousands and tens of thousands, perished, and were swept away on each side of me, there dying in our parish this year 406 of the pestilence!

January 3rd, 1666. I supped in Nonesuch House, whither the office of the Exchequer was transferred during the plague, . . .

March 22nd. The Royal Society reassembled, after the dispersion from the contagion.

April 15th. Our parish was now more infected with the plague than ever, and so was all the country about, though almost quite ceased in London.

June 11th. (Trinity Monday) After a sermon, applied to the re-meeting of the Corporation of the Trinity House, after the late raging and wasting pestilence: I dined with them in their new room in Deptford, the first time since it was rebuilt.

July 22nd. Our parish still infected with the contagion.

July 29th. The pestilence now fresh increasing in our parish, I forbore to go to church.

September 2nd. This fatal night, about ten, began the deplorable fire, near Fish-street, in London.

Then follows a graphic and interesting account of the great fire, terminating with the words:

"Thus I left it this afternoon burning, a resemblance of Sodom, or the last day. It forcibly

> recalled to my mind that passage . . . *nonenim hic habemus stabilem civitatem:* the ruins resembling the picture of Troy. London was but is no more!"

But the fire anticipated the disappearance of the plague for the diary continues:

September 7th. Still the plague continuing in our parish, I could not, without danger, adventure to our church.

October 28th. The pestilence, through God's mercy, began now to abate considerably in our town.

A more complete account of it is to be found in the interesting book by Daniel De Foe. "A Journal of the Plague Year in London." Its publication in the "Everyman's Library" edited by Ernest Rhys, and published by E. P. Dutton and Co. in New York, has put it within reach of all readers.

From these sources it is possible to get a very good idea of the conditions obtaining in the midst of a great and deadly epidemic, though the writers not being men of science do not always give an accurate description of the disease itself. Thus, it is hard to believe the story of the sudden death of the hogs given in the extract from Bocaccio. But it is only natural for every unusual circumstance occurring at such a time, previous droughts, the appearance of comets, and the death of animals to be connected in the minds of the people with the calamity of the time.

An epidemic of plague broke out in the western Chinese province of Yunnan, and reached Canton in January, 1894. Thus escaping from its endemic center, it began to spread. It can be traced from canton to Hongkong, thence in 1895 to Amoy, Macao and Foochoo. By 1896 it had reached Bombay and reappeared in Hongkong. In 1897 Bombay, the Madras Presidency, the Punjab and Madras were visited. In 1898 the disease spread greatly throughout India, and into Turkestan, and by sea went to Madagascar and Mauritius. In 1899 it extended more widely in India, China, and Formosa, and succeeded in disseminating as widely as the Hawaiian Islands and New Caldonia on the east, Portugal, Russia and Austria on the west, and Brazil and Paraguay on the south. In 1900 it spread to nearly every part of the world. Those who may be interested are referred to a pamphlet "The Present Pandemic of Plague" by Dr. J. M. Eager, published in 1908 by the U. S. Public Health and Marine Hospital Service, Washington, D. C.

Plague is an extremely fatal affection, and even at the present time, in places where sanitary measures cannot be enforced, the disease spreads, people die in great numbers. Thus, in India in 1901, there were 362,000 cases with 278,000 deaths. In the

first six months of the epidemic of 1907, the deaths in India were much more numerous, reaching a total of 1,062,908. But where sanitary precautions are possible and co-operation between the authorities and the people successful, as in New York, San Francisco, and other American ports to which

Fig. 41.—Plague bacillus, magnified about 1000 diameters. (*Rowland.*)

the infection was brought, the disease did not spread.

The specific cause of plague is a micro-organism—a bacillus—that was discovered independently and almost simultaneously by a Japanese scientist, Kitasato, and a French bacteriologist, Yersin, who worked in Hongkong during the epidemic of 1894. It is a very small, short bacillus that occurs in great numbers in the "bubos" or swollen lymphatic

glands of the sufferers, and sometimes enters the blood.

And now we come to the most interesting thing about the disease from the standpoint from which we are viewing the epidemic diseases. Plague seems to be primarily a disease of lower animals—marmots and rats—and only secondarily, and one might say accidentally or incidentally, a disease of human beings.

Fig. 42.—Prof. S. Kitasato.

This eminent Japanese scientist was the first to obtain the bacillus of tetanus in pure culture, the first to make tetanus antitoxin, and shares with Yersin the honor of the discovery of the bacillus of plague.

It seems to be endemic in parts of northern India, where the animals no doubt harbor it and

where small numbers of them are constantly dying of it.

A somewhat similar parallel now seems to exist in our own country, for during the outbreak of plague in San Francisco in 1900, the disease was transmitted from the rats of the city to the wood-rats, ground squirrels, and prairie dogs of the surrounding country, some of which may still be infected, and from which it is feared that it may, upon some future occasion, be returned to the rats of the city. What goes on among these rodents and determines that the disease occasionally disseminate, we do not know. But the appearance of plague in epidemic form among human beings is now known to be preceded by an unusual mortality among rats. The outbreak appears, therefore, to be first an epizoötic of rats, and later an epidemic of men.

The disease may be transmitted to man in several ways; first, through the bites of infected fleas; second, drop infection through the inhalation of the bacilli coughed up by those suffering from the occasional pneumonic variety of the disease; and third, by contamination with the discharges from the suppurating bubos, in which large numbers of the bacilli are present.

The accounts of infection from touching the clothing of infected persons, or from simply coming

into their presence, are exaggerations and erroneous observations. With ordinary care there is comparatively little to be feared from contact with the patients themselves. In all probability, a very few cases do originate from contact with the discharges, or through the inhalation of the drops of coughed up pulmonary secretion, but the common mode of transmission seems to be through the bites of fleas. It ought easily to be possible to avoid the other sources of infection, but it is far more difficult to avoid the infected fleas.

All rats, like all dogs, have fleas. But when plague becomes epidemic among the rodents, and many of them die, the proportion of fleas to rat becomes disturbed; there are soon many more fleas per rat than formerly, and the surviving rats have to endure many more bites, with the inevitable result that many more of them are continually becoming infected. Thus far the epidemic may still be confined to the rats; but as the rats die, and the fleas remain alive, new sources of food must be found. Presumably they try all of the warm blooded creatures with which they come into contact, and among them man.

I suppose that I need scarcely tell you that the flea has mouth-parts so constructed that it has no other means of feeding than to suck the blood of

an animal. That is true of all the insects whose habit it is to bite for a livelihood. But mosquitoes that only bite occasionally, can suck the juices of fruits and the nectar of flowers, but once a flea has passed from the larval to the mature stage of development, it must suck blood or starve. Doubtless a rat-flea can live for a time upon any blood, but as different species of fleas inhabit different species of animals, it is doubtful whether they can do so indefinitely. Thus may partly be explained the observation that fleas having left the rats and lived for a time upon the bloods of other animals, sooner or later die. It is also quite possible that the death of the fleas is hastened by infection with plague bacilli, as the following will suggest.

Of the bacilli taken into the flea with the blood it sucks, some may be killed in the stomach, but many seem able to survive, and are later passed out in the intestinal discharges. Any that remain in the crop, and do not reach the stomach also remain alive. The researches of Roger and Bacot have shown that the proventiculus or crop of the flea is lined with very large epithelial cells that give it a peculiar rough surface with numerous recesses in the walls. In these many of the imbibed plague bacilli lodge, and there they multiply until they form a plug. The hungry flea bites, but the blood being

unable to pass the plug, the insect makes violent sucking movements to overcome the obstruction, with the result of breaking up the plug, parts of which enter the proboscis and are forced into the

Fig. 43.—Roger and Bacot's idea of the method of plague infection by fleas.

The upper larger illustration is a diagrammatic representation of the proboscis and pharynx of a flea. At *p*, the large epithelial cells that give the interior of the pharynx its roughness, are shown. The vague dark mass caught there represents plague bacilli.

The lower smaller illustration shows how these masses of bacilli, becoming detached, and too large to be swallowed, interfere with subsequent feeding, and breaking up as the flea violently sucks in an effort to satisfy its appetite, may pass through the proboscis into the animal whose blood the insect attempts to suck.

tissues of the creature bitten. It seems to be through this accident that the transmission of the

plague bacilli is effected by the flea. There is, however, another possibility. If the flea bite successfully, and is loading itself with blood, it evacuates its intestine, depositing the contents upon the skin as a tiny flea spot. As the bite subsequently itches, the man or animal bitten, scratches, and with his nails infects himself from any bacilli in the flea spot. Both of these methods of flea infection have their adherents. Both may be true. Certainly the observations of Roger and Bacot seem to prove their case, and it is probable that the bite is the more frequent means of transmission.

From a perusal of the historical writings that have been recommended, you will discover that plague has nothing whatever to do with poverty, dirt or method of living. We are expressly told that the infection seemed to be in the air and to descend upon the people. We can understand how that is when we realize that the fleas spreading the infection may be anywhere and leap upon any body. Rats are great travellers, and in the best kept houses they not unexpectedly take up residence and may be extremely difficult to dislodge. In the case of an epidemic when so many houses are closed, the surviving rats, shut off from their customary source of food, seek other haunts, with the result that open houses belonging to the best people may

be invaded, and infected fleas escape to transmit the disease to the occupants. But it must be remembered that there are also *human* fleas as well as rat fleas, so that once the epidemic is started, they may keep on transmitting the bacilli from man to man indefinitely.

In the light of present information, communities without rats and fleas are safe from plague, but such are few; rats and fleas abound almost everywhere.

In passing, it may be worth while to call attention to the prevailing careless and almost criminal indifference to rats. It is estimated that in our country these rodents destroy grain and other foods to the value of some $20,000,000 each year, besides effecting an almost equal amount of damage to other property. How can we be so neglectful as to let that pass unnoticed? Why do we tolerate rats? Why not at once enter upon a campaign of extermination on economical grounds? It would have the double benefit of saving money, and promoting the public safety.

It has been pointed out with respect to nearly every disease that has been discussed that it is much more easy to prevent its getting into a place than to eradicate it when once established there. And so it is with the plague.

TO PREVENT PLAGUE FROM GETTING INTO A PLACE.

Where there are no rats there will be little plague. therefore. one should begin by exterminating the rats. In San Francisco they waited until the plague had come. and then set about killing the rats and making the city rat proof. How much wiser it would be to prepare for such an emergency in advance. and avoid the necessity of suddenly incurring an extraordinary expenditure of public funds! It is not difficult. and can be effected gradually. If in the issuance of every permit for building or alterations it were specified that nothing but concrete basements with raised elevations and netted entrances would be allowed. the hiding places and tunnelling operations of the rats would soon become impossible and in the course of time the whole city would become more or less rat proof. In some cities this is already being done and the slight increase in the cost of building is more than offset by what is saved from the rats.

TO KEEP THE DISEASE FROM SPREADING WHEN IT GETS IN.

To prevent an epidemic of plague and the consequent desolation described by Bocaccio and De Foe is the prime objective of the sanitary officer.

Fig. 44.—Rat examination at the laboratory in Bombay City. (Report on Plague Investigation in India.)

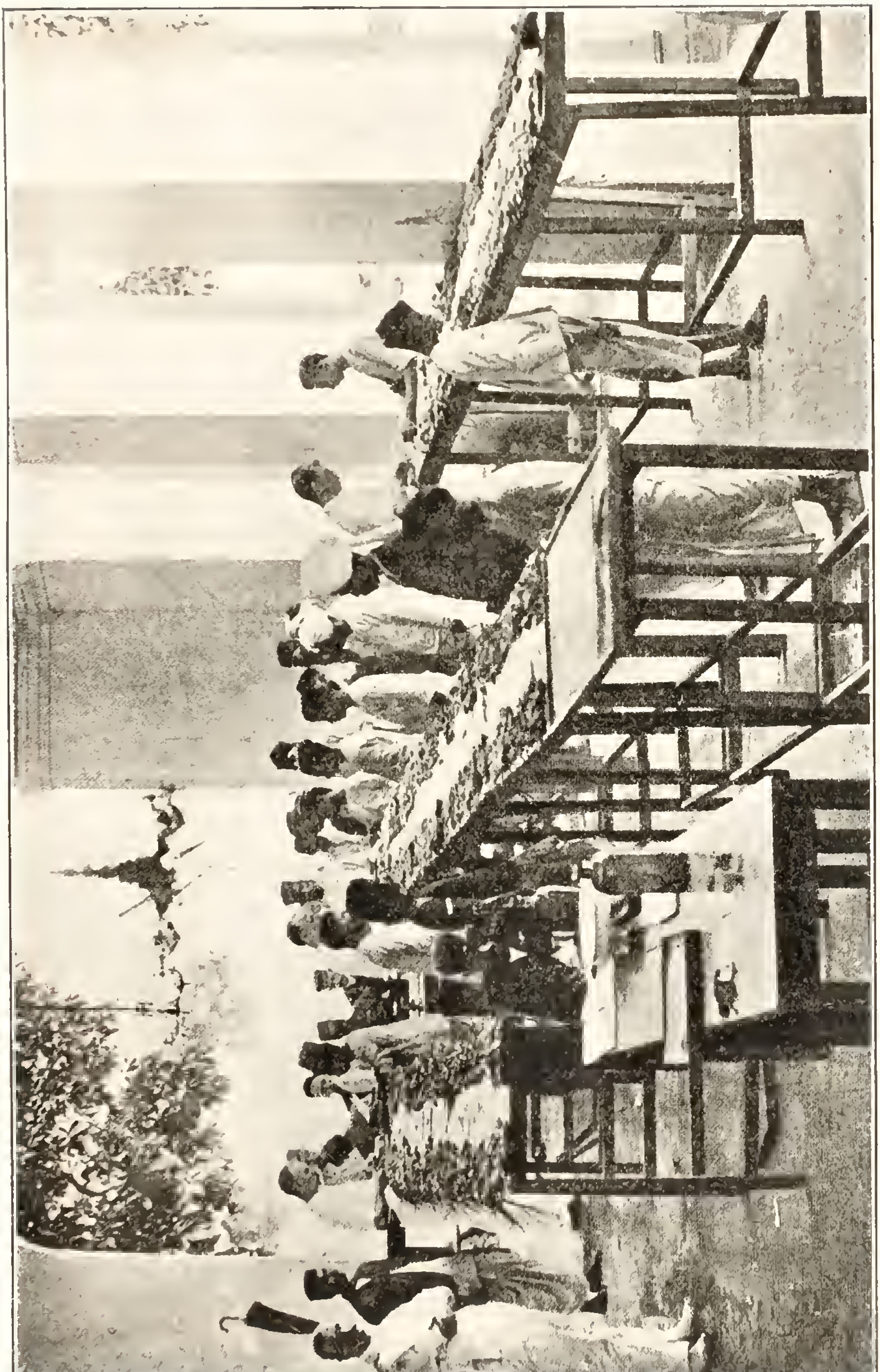


Fig. 45.—Rat examination at the laboratory in Bombay City. (Report on Plague Investigation in India.)

There are three things to which immediate attention must be devoted; the patients, the rats, and the fleas.

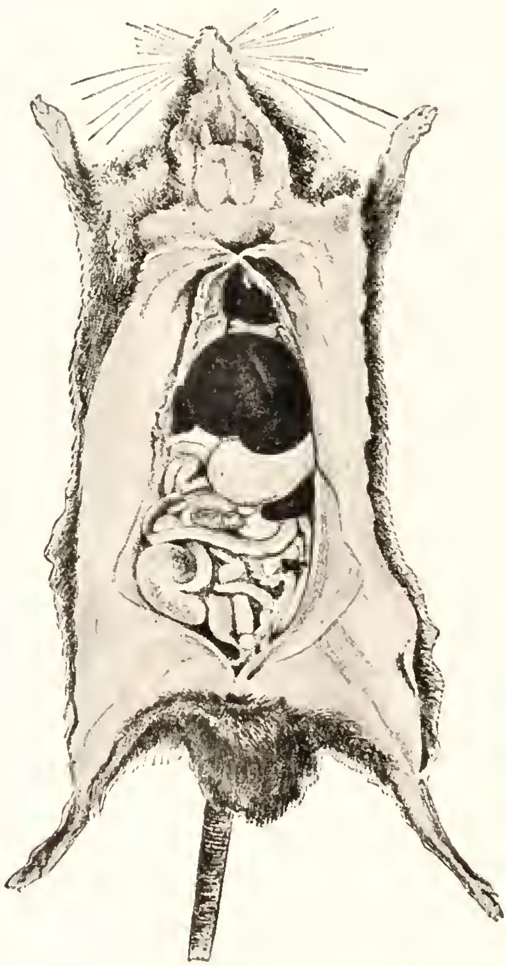


Fig. 46.—Body of a healthy rat, opened so as to show the viscera.

(1) ***The Rats.*** A large mortality among the rats is the usual first indication that the disease is at large, and when dead rats are found here and there grave misgivings should always be felt, and

Fig. 47.—Plague-infected rat. A composite picture, illustrating some of the common naked-eye pathological changes found in various organs and tissues in a plague-infected rat. Note marked subcutaneous congestion causing a peculiar pink appearance of the tissues; submaxillary bubo; subcutaneous punctate hemorrhages most frequently found in the neck; marked congestion and hemorrhages in the thoracic cavity, especially in the lungs; advanced stage of mottled granular liver; and enlarged and congested spleen.

bacteriological examination of the rats made to see of what they have died. Should a case of plague appear in any city, no time should be lost in starting a thorough campaign of extermination against the rats. Men should be especially hired for the purpose, provided with appropriate traps, and paid to catch the animals as fast as possible, everywhere, but especially in the district in which the disease appeared. As the traps are brought into the laboratory, each should be inclosed in a bag, and the animals killed with chloroform, the fleas, of course, dying with them. As soon as they are dead, the fleas should be carefully picked off and bottled up, and the rats examined postmortem for the purpose of finding how many of them are infected. But let no one come to the hasty conclusion that because but few of the rats seem to be infected the catching and killing of them can be stopped.

Not until rats from all sections of the city have been carefully examined, and no more infected ones found, for a considerable period of time, is it safe to let up on the rat campaign. Every rat destroyed with its fleas is just so much property saved from destruction by that rat, and perhaps just so much safety from infection by its fleas, contributed to the human population.

In San Francisco the destruction of the rats having been begun too late had to be continued for twenty years. Until quite recently it was disheartening to find an occasional plague-infected rat long after the job was supposed to be finished.

(2) *The Patient.* As the patient is himself but a very moderate source of danger, all that is necessary to do with him is to remove him at once to a hospital for infectious diseases in which he will cease to infect any fleas, either human or animal fleas, that might otherwise suck his blood; in which he can be given every medical, surgical and sanitary attention and in which his bubos can be properly dressed and the discarded bandages incinerated so that they cannot infect either human beings or rats. If the case develops pneumonia the usual precautions must be taken to prevent "drop infection" of the attendants.

(3) *The Fleas.* It is very difficult to deal with the fleas apart from the rats. The insects living upon their various animal hosts, lay eggs without cementing them to the hairs or clothing, as the lice do, and so let them fall upon the ground. From each, in the course of time a tiny worm-like larval creature escapes to live upon such vegetable matter as it finds upon the ground, until it has grown, when it spins a tiny silken cocoon, passes first into

the pupa stage, and then having completed its metamorphosis escapes from its cocoon, an active and hungry adult flea ready to leap upon the first rat that comes along. Where fleas abound their eggs, larvæ and cocoons are, no doubt, numerous

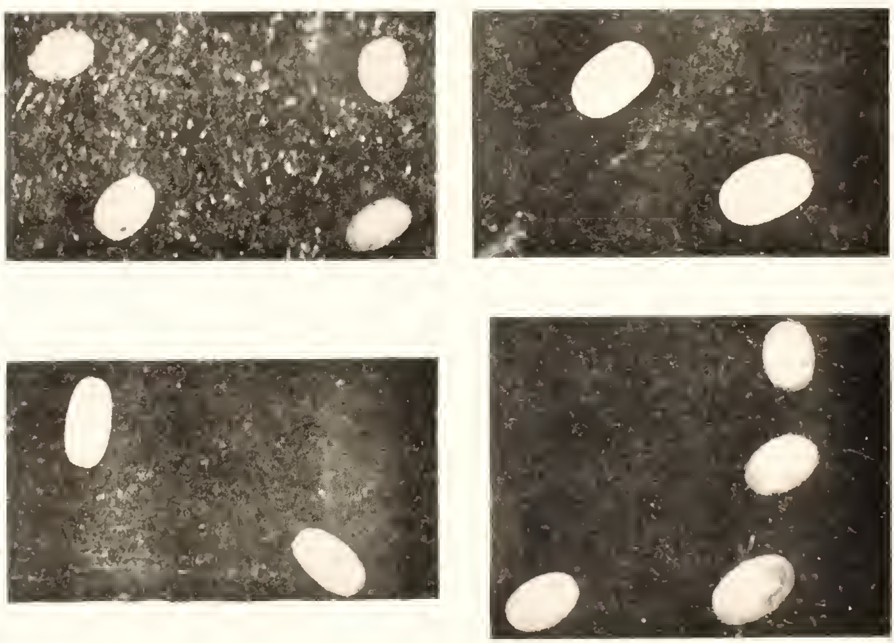


Fig. 48.—Eggs of various fleas. (*Bacot.*)

upon the floors, but one cannot be sufficiently sure where they are to set about any definite campaign of extermination. General domestic cleanliness, and the frequent use of the broom are the best methods of procedure.

Owners of house dogs and cats are sometimes surprised, when returning home after a summer vaca-

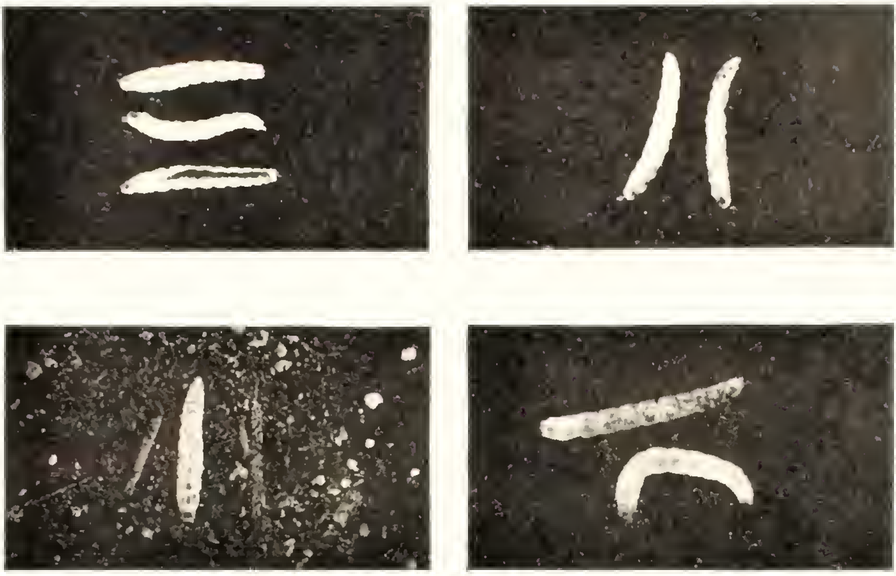


Fig. 49.—Larvæ of various fleas. (*Bacot.*)

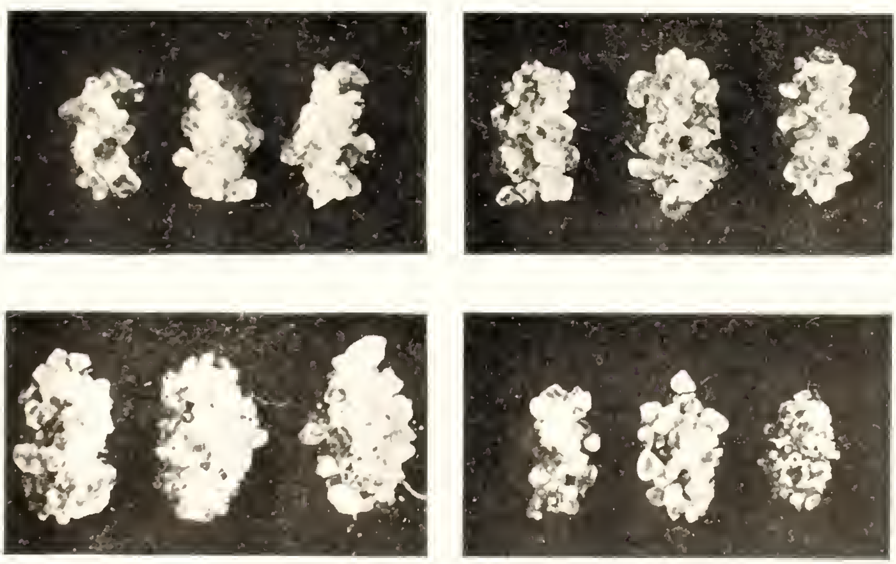


Fig. 50.—Cocoons of various fleas. (*Bacot.*)

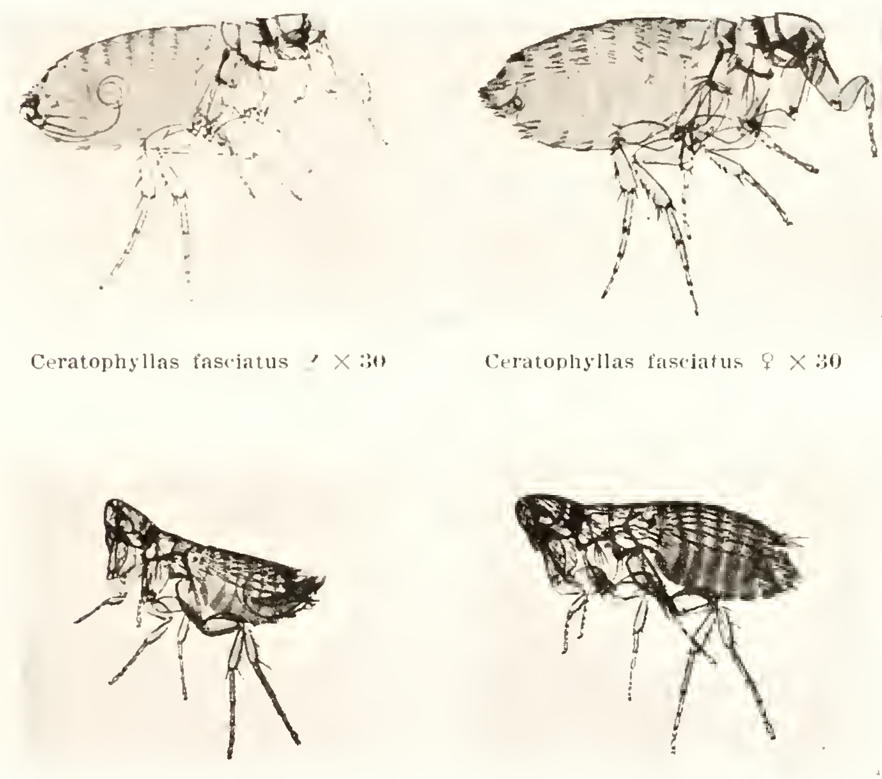
tion, during which the house has been closed and empty, to find themselves welcomed by swarms of fleas.

Where can the insects have come from? It is a very simple matter to explain. The eggs and

Fig. 51.—Pupæ of various fleas and cocoons of Ctenocephalus canis. (*Bacot.*)

larvæ of the fleas were upon the floors; during the period of closure they grew to maturity, and with the return of the family were hungrily waiting to attack the dog, cat, or humans as might happen. In one such "epidemic of fleas" that I investigated, all were dog fleas. Sometimes the house is found to contain fleas though there has been no dog or cat in the family. Under these conditions mice in

the house were the probable source of the eggs and larvæ, which remained after the little animals, finding no food because the larder was not replenished, had removed to other quarters. There are, of



Ceratophyllas fasciatus ♂ × 30 Ceratophyllas fasciatus ♀ × 30

Leptopsylla musculi ♂ × 30 Leptopsylla musculi ♀ × 30

Fig. 52.—Adults of various fleas. (*Bacot.*)
(Journal of Hygiene, vol. xiv, 1904. Plague Supplement 3.)

course, some houses in which human fleas abound, but in our country, most of the fleas found biting human beings are those normally parasitic upon dogs, cats, rats and mice.

An excellent method of catching fleas in infected houses, is to place a cage containing an animal—puppy, kitten, white rat, guinea-pig, or rabbit in the center of the room carefully surrounding it everywhere with "sticky fly paper." The fleas not being able to spring more than a few inches, are caught upon the adhesive surface of the paper as they endeavor to reach the imprisoned animal.

AFRICAN LETHARGY OR SLEEPING SICKNESS.

African lethargy is a disease of equatorial Africa, where it is of frequent occurrence among the native populations, and occasionally affects European visitors. It is not to be confused in your minds with the disease of this country with which the newspapers have recently made you acquainted under the name "sleeping sickness." The two are similar in symptoms, but entirely different in causation.

The first account of this interesting affection seems to appear in the appendix of a little book called "The Navy Surgeon; or A Practical System of Surgery," published in 1734 by John Atkins, Surgeon. Here is what he says about it:

> The Sleepy Distemper (common among the Negroes) gives no other previous Notice, than a Want of Appetite two or three Days before; their Sleeps are sound, and Sense

of Feeling very little: for pulling, drubbing, or whipping, will scarce stir up Sense enough to move: and the Moment you cease beating, the Smart is forgot and they fall again into a State of Insensibility, drivelling constantly from the Mouth, as if in a deep state of Salivation: breathe slowly, but not unequally, nor snort. Young People are more subject to it than the Old: and the Judgment generally pronounced is Death, the Prognostic seldom failing. If now and then one of them recovers, he certainly loses the little Reason he had, and turns Ideot.

A somewhat better and more lengthy description is to be found in "An Account of Native Africans in the Neighborhood of Sierra Leone" by Dr. Thomas Mastermann Winterbottom, and published in 1803. He describes it thus:

The Africans are very subject to a species of lethargy, which they are much afraid of, as it proves fatal in every instance. The Timmanees call it márree, or 'nluoi, and the Bulloms, nagónlôe, or kadeera: it is called by the Soosoos, kee kóllee kondee, or sleepy sickness, and by the Mandingos, seenoyuncaree, a word of similar import. This disease is very frequent in the Foola country, and it is said to be much more common in the interior parts of the country than upon the sea coast. Children are very rarely or never, affected with this complaint, nor is it more common among slaves than among free people, though it is asserted that the slaves from Benin are very subject to it. At the commencement of the disease, the patient has commonly a ravenous appetite, eating twice the quantity of food that he was accustomed to take when in health, and becoming very fat. When the disease has continued sometime, the appetite declines, and the patient gradually wastes away. Squinting occurs sometimes, though very seldom, in this

disease, and in some rare instances the patient is carried off in convulsions. Small glandular tumors are sometimes observed in the neck a little before the commencement of this complaint, though probably depending rather upon accidental circumstances than upon the disease itself. Slave traders, however, appear to consider these tumors as a symptom indicating a disposition to lethargy, and they never buy such slaves, or get quit of them as soon as they observe any such appearances. The disposition to sleep is so strong as scarcely to leave a sufficient respite for the taking of food: even the repeated application of a whip, a remedy which has frequently been used, is hardly sufficient to keep the poor wretch awake. The repeated application of blisters and of setons has been employed by European surgeons without avail, as the disease, under every mode of treatment, usually proves fatal within three or four months. The natives are totally at a loss to what cause this complaint ought to be attributed: sweating is the only means they make use of, or from which they hope for any success: this is never tried but in incipient cases, for when the disease has been of any continuance they think it in vain to make the attempt. The root of a grass, called by the Soosoos kallee, and the dried leaves of a plant, called in Soosoo fingka, are boiled for some time in water, in an iron pot; when this is removed from the fire, the patient is seated over it, and is covered over with cotton cloths, a process which never fails to excite a copious perspiration. This mode of cure is repeated two or three times a day, and is persisted in for a considerable length of time, until the disease be carried off, or appears to be gaining ground. No internal medicines are given in the complaint.

In both of these old books the interest of the authors had to do with slaves, among whom they saw cases of the disease.

Occasional cases, in slaves, are said to have been imported into this country, and I have been told that mention of it is made in some of the documents before the negro emancipation at the time of the Civil War.

It is said that a clause was sometimes inserted into sales agreements by virtue of which "if a newly imported slave should die of the sleeping sickness within a certain time, the vendor was bound to replace him by another as good." I have not been able to confirm either of these statments, but there seems to be little reason to doubt them.

But whatever knowledge of it may have been in existence during those early days seems to have disappeared, and I have looked in vain for some mention of "African lethargy" or "sleeping sickness" in the books used at the time that I was a student.

Indeed, it seems to have been practically unknown here as recently as 1900, for about that time it first came under my own notice. The circumstance was as follows. An African negress, brought up in a Mission School on the Congo River, and subsequently educated in this country, returned to Africa to be a medical missionary to her own people. A few years later she again came to America in great distress, saying that she discovered herself to be suffering from the early symptoms of a common and terri-

bly fatal disease of her own country, "sleeping sickness." She went from one to another of the doctors of her acquaintance seeking for advice, but met with nothing but ignorance of the affection she had learned to know so well. Eventually she fell into the drowsy stage of the malady, and finally died after prolonged coma, in a Philadelphia hospital, where

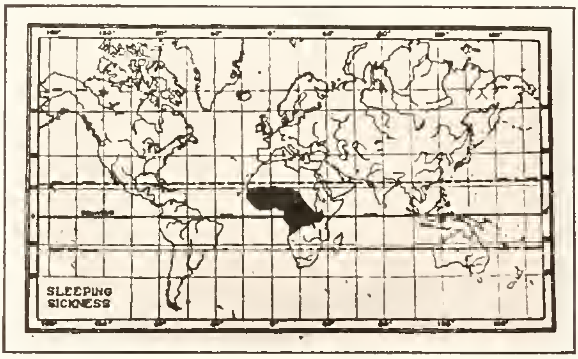


Fig. 53.—Map showing geographical distribution of African sleeping sickness. (*Stitt.*)

The black area embraces nearly all of the well-watered, well-forested area drained by the Congo River. The disease is scarcely known elsewhere.

I was called upon to perform an autopsy and endeavor to find out why. I examined her body painstakingly, but found nothing adequate to explain her death, and not knowing how to proceed further, I probably lost an opportunity and left the discovery of the specific micro-organism to others, as we shall see.

The disease was very puzzling, and Sir Patrick Manson thus spoke of it in his Lane Lectures delivered in this country in 1905:

Fig. 54.—Congo negro with sleeping sickness in an early stage. (*Manson.*)

For upwards of a century students of tropical pathology have been puzzled over a peculiar striking African disease, somewhat inaccurately described by its popular name, the sleeping sickness. Its weirdness and dreadful fatality have gained for it a place not in medical literature only, but also in general literature. The mystery of its origin, its slow but sure advance, the prolonged life in death that so often characterizes its terminal phases, and its inevitable issue,

have appealed to the imagination of the novelist, who more than once has brought it on his mimic stage, draping it, perhaps, as the fitting nemesis of evil doing.

In his book upon "Tropical Medicine," he describes the diseased patient as follows:

. . . the first indications of the oncoming of sleeping sickness are merely an accentuation of the debility and languor usually associated with trypanosome infection.

Fig. 55.—Basugo negro, boy of 16, with sleeping sickness in a late stage. (*Bruce, Nabarro* and *Grieg.*)

There is a disinclination to exertion: a slow, shuffling gait: a morose, vacant expression; a relaxation of the features; a hanging of the lower lip; a puffiness and drooping of the eyelids: a tendency to lapse into sleep or a condition simulating sleep: a slowness in answering questions; a shirking of the day's task. Dull headache is usually present. Later there may be fibrillary twitching of the muscles, especially of the tongue, and tremor of the hands, more rarely of the legs, indicating a definite implication of the motor centers. By this time the patient has taken to bed, or he lies about in a corner of his hut, indifferent to everything going on about him, but still able to speak or take food if brought

to him. He never spontaneously engages in conversation or asks for food. As torpor deepens he forgets even to chew his food, falling asleep perhaps in the act of conveying it to his mouth, or with the half masticated bolus still in his cheek. Nevertheless, such food as he can be got to take is digested and assimilated. Consequently if he is properly nursed at this stage there may be no general wasting. As time goes on he begins to lose flesh, tremor of the hands become more marked, and convulsive or choreic movements may occur in the limbs or in limited muscular areas. Sometimes these convulsions are followed by local temporary paralysis. Sometimes there is rigidity of the cervical muscles and retraction of the head. Bedsores tend to form, the lips become swollen, the saliva dribbles from the mouth; gradually the lethargy deepens, the body wastes, the bedsores extend, the sphincters relax, and finally the patient dies comatose or sinks from slowly advancing asthenia. Possibly he succumbs to convulsions, hyperpyrexia, pneumonia, dysentery or other intercurrent condition.

The cause of this peculiar and interesting affection, and its mode of transmission were not known until 1903. They were not the work of one man, nor the sudden and independent results of genius, but were built up upon the combined work and separate observations of a number of investigators in different parts of the world.

I shall dwell upon sleeping sickness at greater length than with some of the other affections considered, not because its importance to us, in this country, merits it, but because the brilliant investigations that led up to present knowledge of it, make it a fit

text for an understanding of the way in which scientific investigation is carried on. To this end I shall now interrupt the discussion of sleeping sickness for the purpose of considering another disease, the investigation of which greatly contributed to our understanding of it. This is not a disease of men, but of lower animals, occurs almost exclusively in Africa, and is known as "Nagana" or "tse-tse fly disease."

TSE-TSE FLY DISEASE OF CATTLE.

Equatorial Africa is still a very interesting place, as those who have read Theodore Roosevelt's book must have found. But for those who went first it was very much more interesting with its strange climates, its great plains and forests, its great rivers, lakes and water-falls; its new insects and animals, and its peculiar black men.

In these strenuous times when there are so many new, interesting and profitable books, it is hard to find time to look at older ones, but certain of them are profitable, and I cannot refrain from recommending those of David Livingstone and Henry M. Stanley.

Now if you have read or will read these, you cannot fail to be impressed by the mention of a peculiar and fatal disease, limited to restricted districts,

occasioned by peculiar flies, and from which the explorers lost many of the cattle, horses and dogs belonging to the expeditions. It was called "Tse-tse fly disease," because even the natives of the country were well acquainted with the fact that it followed the bites of these insects.

Here is what David Livingstone says about it in his book "Missionary Travels and Researches in South Africa," published by Harper Brothers, New York, 1858:

Across the River Sonta, and to the bank of the Chobe in the country of Sibituane, we had to pass through another tse-tse fly district by night, and at once passed our cattle over to the northern bank to preserve them from its ravages.

A few remarks on the tse-tse, or Glossina morsitans, may here be appropriate. It is not much larger than the common house fly, and is of the same brown color as the common honey bee; and the after part of the body has three or four yellow bars across it; the wings project beyond this part considerably, and it is remarkably alert, avoiding most dextrously all attempts to capture it with the hand at common temperatures; in the cool of the mornings and evenings it is less agile. Its peculiar buzz when once heard can never be forgotten by travellers whose means of locomotion are domestic animals; for it is well known that the bite of this poisonous insect is certain death to the ox, horse and dog. In this journey, though we were not aware of any great number having at any time alighted on our cattle, we lost forty-three fine oxen by its bites. We watched the animals carefully and believe that not a score of flies were upon them.

A most remarkable feature in the bite of the tse-tse is its perfect harmlessness for man and wild animals, and even calves, so long as they continue to suck the cows. We never experienced the slightest injury from them ourselves, personally, though we lived two months in their *habitat,* which was, in this case, as sharply defined as in many others, for the south bank of the Chobe was infected by them, and the northern bank, where we placed our cattle, only fifty yards distant, contained not a single specimen.

Fig. 56.—Glossina morsitans. The definitive host of Trypanosoma brucei, of Nagana. Natural size. (*Austin.*)

This was the more remarkable, as we often saw natives carrying over raw meat to the opposite bank with many tse-tses settled on it.

The poison does not seem to be injected by the sting, or by ova placed beneath the skin; for when one is allowed to feed freely on the hand, it is seen to insert the middle prong of three portions into which the proboscis divides, somewhat deeply into the true skin: it then draws it out a little way, and it assumes a crimson color as the mandibles come into brisk operation. The previously shrunken belly swells out, and, if left undisturbed, the fly quickly departs when it is full. A slight itching irritation follows, but not more than in the bite of a mosquito. In the ox this bite

produces no more immediate effect than in man. It does not startle him as the gad-fly does; but in a few days afterward the following symptoms supervene; the eye and nose begin to run, the coat stares as if the animal were cold, a swelling appears under the jaw, and sometimes at the navel; and though the animal continues to graze, emaciation commences, accompanied by a peculiar flaccidity of the muscles, and this proceeds unchecked until, perhaps three months afterwards, purging comes on and the animal, no longer able to graze, perishes in a state of extreme exhaustion. Those which are in good condition often perish soon after the bite is inflicted, with staggering and blindness, as if the brain were affected by it. Sudden changes of temperature produced by falls of rain seem to hasten the progress of the complaint; but in general, the emaciation goes on uninterruptedly for months, and do what we will, the poor animals perish miserably.

When opened, the cellular tissue on the surface of the body beneath the skin, is seen to be injected with air as if a quantity of soap bubbles were scattered over it, or a dishonest awkward butcher had been trying to make it look fat. The fat is of a greenish-yellow color and of an oily consistence. All the muscles are flabby, and the heart often so soft that the fingers may be made to meet through it. The lungs and liver partake of the disease. The stomach and bowels are pale and empty, and the gall-bladder is distended with bile.

These symptoms seem to indicate what is probably the case, a poison in the blood, the germ of which enters when the proboscis is inserted to draw blood. The poison germ contained in a bulb at the root of the proboscis, seems capable, although very minute in quantity, of reproducing itself, for the blood after death by tse-tse is very small in quantity, and scarcely stains the hands in dissection. . . .

The mule, ass and goat enjoy the same immunity from tse-tse as man and the game. Many large tribes on the Zam-

besi can keep no domestic animals except the goat in consequence of the scourge existing in their country. Our children were frequently bitten, yet suffered no harm, and we saw around us numbers of zebras, buffaloes, pigs, pallahs, and other antelopes, feeding quietly in the very habitat of the tse-tse, yet as undisturbed by its bite as oxen are when they first receive the fatal poison. There is not so much difference in the nature of the horse and the zebra, the buffalo and the ox, the sheep and the antelope to offer any satisfactory explanation of the phenomenon. Is man not as much a domestic animal as a dog? The curious feature in the case, that dogs perish though fed on milk, whereas the calves escape so long as they continue sucking, made us imagine that the mischief might be produced by some plant in the locality, and not by tse-tse; but Major Vardon, of the Madras Army, settled that point by riding a horse up a small hill infested by the insects, without allowing him time to graze, and though he only remained long enough to take a view of the country, and catch some specimens of the tse-tse on the animal, in two days afterward the animal was dead.

The well-known disgust which the tse-tse shows to animal excreta as exhibited when a village is placed in its habitat, has been observed and turned to account by some of the doctors. They mix droppings of the animals, human milk and some medicines together and smear the animals that are about to pass through a tse-tse district; but this, though it proves a prevention at the time, is not permanent. There is no cure yet known for the disease. A careless herdsman, allowing a large number of cattle to wander into a tse-tse district, loses all except the calves; and Sibituane once lost nearly all of the entire cattle of his tribe: many thousands, by unwittingly coming under its influence. Inoculation does not insure immunity, for animals which have been slightly bitten in one year, may perish by a greater number of bites in the next; but it is probable that with the influence of

guns the game will perish, as has happened in the south, and the tse-tse deprived of food may become extinct simultaneously with the larger animals.

We are not sure just what Dr. Livingstone had in mind when he said—"The poison germ contained in a bulb at the root of the proboscis, seems capable, though present in very minute quantity, of reproducing itself, etc." He may have suspected it to be a micro-organism, or have thought of it as some kind of enzymic substance. Megnin, in 1875, however, expressed the opinion that "the tse-tse flies carry a virus and do not inoculate a poison of their own," and in 1879 Drysdale suggested that the flies might act as the intermediate host of some blood parasite. Nocard, in 1884, suspecting the same thing showed that inoculations made with the proboscides of tse-tse flies were harmless.

THE DISCOVERY OF THE CAUSE OF TSE-TSE FLY DISEASE.

It is to Sir David and Lady Bruce that we are indebted for the discovery of the true cause of the tse-tse fly disease. Working in Africa, they found in the bloods of infected animals, and in experimentally infected dogs and smaller animals, a peculiar minute, spindle-shaped protozoan micro-organism known as a *Trypanosome*.

Having found the specific micro-organism it was only a step to show that it was transmitted by the tse-tse flies, and thus to work out the whole story of "Nagana," as the tse-tse fly disease is now called.

But, someone will say, what has all this to do

Fig. 57.—Sir David Bruce.
Sir David and Lady Bruce, discovered the trypanosome of Nagana or tse-tse fly disease.

with sleeping sickness in man? It is a very proper question, but wait!

DISCOVERY OF TRYPANOSOMES IN THE BLOOD OF MAN.

In 1901, at Bathhurst, Gambia, Dr. Forde examined the blood of a white man, the captain of a steamboat, who had navigated the Gambia River

Fig. 58.—Trypanosoma brucei, the parasite of Nagana or tse-tse fly disease, in the blood of a dog.

The micro-organisms are elongate and serpentine, and swim with the rapidity and sinuous movement of eels, also rotating about the long axis. Those most distinct in the illustration are toward the lower left third. The indistinct round bodies are red blood corpuscles.

for six years. He was at the time suffering from peculiar irregular febrile attacks, that might be malarial. In the blood Forde found no malarial parasites, but did find a very peculiar actively motile micro-organism unknown to him, and which he described as a "small worm-like body." Later the blood of the same patient was examined again by Forde and Dutton, and the latter recognized in the peculiar bodies, trypanosomes. They were later called *Trypanosoma gambiensi.* The patient died in England, in 1903.

Interested in these micro-organisms that had not before been encountered in the blood of men, Dutton and Todd examined the bloods of 1000 persons in Gambia, and were rewarded by finding them in six natives and one quadroon. In the same year, 1903, Manson, in London, found them in the bloods of two Europeans returned from the Congo district, where they had acquired the infection. Through these and other observations the occurrence of human infection by trypanosomes became recognized.

But during this time no one had suspected any connection between these micro-organisms and any other malady.

To return, now, to the sleeping sickness, Castellani, an Italian investigator, studied it in Uganda.

and came to the conclusion that it was caused by a diplococcus—the Hypnococcus which he had occasionally found, but with which he had failed to

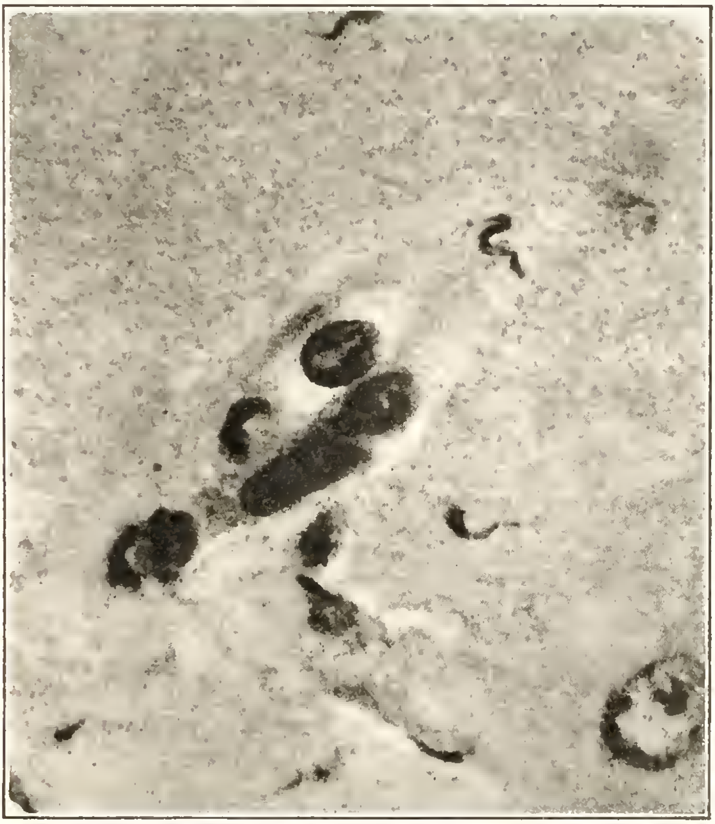


Fig. 59.—Trypanosoma gambiensi in the cerebral substance of a case dying of African lethargy. (*Wohlbach* and *Binger.*)

A single micro-organism is seen at the very top edge of the illustration, several others lower down. The large dark bodies in the center of the illustration are cells in and about a capillary vessel, and of no importance. The granular back-ground is the white substance of the brain.

reproduce it experimentally. Upon one occasion, as he was examining the cerebrospinal fluid of a

case of sleeping sickness, he was surprised to find trypanosomes. This was sufficiently suggestive to be followed up, and it was not long before Castellani came to the conclusion that he was entirely wrong about the Hypnococcus, and that the trypanosomes were the cause of the disease. Eventually he said so in print, calling the newly found micro-organism *Trypanosoma castellani.* It was not at that time supposed to have anything to do with *Trypanosoma gambiense.* But later, through the continued study of sleeping sickness, the two were identified.

It is now known that in the early stages of the sleeping sickness, when there is fever, as in Forde's case, and before the sleepy stage comes on, the parasites are present in the blood of the victim. Later the micro-organisms practically disappear from the blood and invade the central nervous system, appearing in considerable numbers in the cerebrospinal fluid, and actually boring into the substance of the brain and spinal cord. Hence different stages appear like two different diseases; the early stage in which the parasites are in the blood, observed by Forde, Dutton, Todd, and Manson, and the later one with sleeping sickness, in which they are in the cerebrospinal fluid, as observed by Castellani.

But it still remained to discover how the trypanosomes were acquired—how one became infected with sleeping sickness.

If we now return to the tse-tse fly disease, and recall that it produces its fatal effects through the transmission of the micro-organism known as the *Trypanosoma brucei*, I think you will find the circumstance very suggestive.

If a disease of animals caused by trypanosomes is transmitted by tse-tse flies, may not a similar disease of man also be so transmitted? The thought would certainly be justified, and warrant investigation: but if you jumped to the hasty conclusion that because the one was, the other must be, you might be led into egregious blunder. For example, there is another trypanosome disease of lower animals—horses—known as *dourine*, in which the trypanosomes are transmitted from animal to animal directly, without the intermediation of any insect. In this connection I cannot forget a conversation once held with the well-known scientist Metchnikoff, at the Institut Pasteur in Paris. He and I were discussing a certain matter, when I inquired whether it would not be proper to make a certain deduction. To my mind it seemed very clear. His answer was in these words: "We have no *a priori* right to conclude that this or that is the truth;

every thing must be investigated for and by itself alone."

TSE-TSE FLIES AND SLEEPING SICKNESS.

Two excellent parasitologists, Sambon and Brumpt, suspected that the tse-tse flies might be the transmitting agents, as soon as the cause of the

Fig. 60.—Glossina palpalis, the definitive host of Trypanosoma gambiensi, the cause of African lethargy in "sleeping sickness." Life size. (*Austin.*)

disease was shown to be trypanosomes. But an unexpected difficulty was encountered; the well-known tse-tse fly, Glossini morsitans, did not correspond with sleeping sickness in geographical distribution. That is to say, sleeping sickness occurred where there were none of those flies. This was discouraging, but entomologists came to the assistance of the microbiologists, and it was soon shown that the Glossina morsitans is but one of a considerable

family of tse-tse flies, and at the present time at least a dozen species are known. Of these one, the Glossina palpalis, has a distribution corresponding with that of sleeping sickness. It was therefore

Fig. 61.—Monkey with experimentally produced sleeping sickness. (*Bruce, Nabarro* and *Grieg.*)

next suspected of being the transmitting agent, and experiments made upon monkeys and other lower animals have shown it to be. For a long while Glossina palpalis was thought to be the only fly capable of acting as the transmitter of the disease,

but additions have since been made to knowledge of the subjeet. In Rhodesia a very virulent form of the sleeping sickness is now known to be caused by a slightly different miero-organism, to whieh the name *Trypanosoma rhodesiensi* has been given, and that micro-organism can be transmitted either by Glossini palpalis or Glossina morsitans.

I am sure that you now begin to realize that the etiology of sleeping siekness was difficult to work out. But the disease is too important not to merit the attention of the best brains in the world.

ECONOMIC IMPORTANCE OF SLEEPING SICKNESS.

To give an idea of the prevalence and destructiveness of sleeping siekness, Corre has reported that "many native villages in Senegambia have been depopulated." Manson tells that many islands in the Victoria Nyanza have been completely depopulated. Bruce has shown that at Entebbe about 30 per cent. of the population harbor the parasites, and as the infeetion in the natives is almost always fatal, the gravity of that report is self evident. The population of the implicated districts of Uganda, originally 300,000, has in six years been reduced by sleeping sickness alone to 100,000.

But, someone will say, has this not always been the case? No, it is a matter of comparatively re-

Fig. 62.—Buvuma Islands. Sleeping sickness and starvation. From Royal Society, Reports of the sleeping sickness Commission, Supp. 1-5. (*Christy*, 1903.)

cent date, and for this spread of the disease the coming of the white man is responsible.

The missionary, the explorer, the army, the merchant, the railroad, and the movements of commerce are the great incriminating factors. Natives from the interior have been brought to the coast, and those from the coast into the interior, in large numbers, and populations have been shifted about in response to the will of the white man with his thirst for ivory, rubber, and other native products. Moreover, as he has opened up the country, the game animals have been driven from one part to another with results that will be appreciated more fully later.

There is but little doubt that in the last decade the total number of deaths from sleeping sickness in all parts of the continent amounted to not less than a million. Hundreds of thousands are now suffering from it who in the course of a comparatively short time must die.

PART PLAYED BY WILD ANIMALS IN SLEEPING SICKNESS.

The discussion of this disease was begun with the assertion that it was one common to men, insects and wild animals. Thus far only the man and the insects have been mentioned. If there were nothing

else there would be hope that through the application of measures similar to those governing the management of the other infectious diseases studied, sleeping sickness might soon be exterminated; but the other factor adds such serious complication as to be very discouraging to those engaged in the work.

Drs. Kinghorn and Yorke, observed that in the Luangwa Valley, where sleeping sickness abounds, there are many tse-tse flies, and but few domestic animals, though wild game is plentiful. It occurred to them to examine the bloods of a number of these wild animals. As a result, they found the antelopes infected with trypanosomes, apparently identical with those of the sleeping sickness, and now it is supposed that antelopes are the natural carriers from which the tse-tse flies infect themselves and later men.

EXPLANATION OF THE RESISTING POWER OF THE ANTELOPES.

A while back, when we were talking about measles, it was pointed out that we, meaning the Europeans and Americans, have suffered from it for untold generations. An attack is usually followed by an immunity that lasts as long as the individual lives, but is not transmitted to his de-

scendants—our children are born susceptible to it. Yet they are not so susceptible as are the people of the islands of the Pacific Ocean, to whom measles, a new disease, has been a terrible scourge, killing them in large numbers. We are not fully able to explain the difference in the fatality between the disease in us and them, but it seems reasonable to attribute it to natural selection. A good many of us still die of measles and presumably those that die are the more susceptible, and those that survive, the less so. In the course of centuries, the greater part of the less resisting stock has been killed off, and the more resisting remains. We represent only the more resisting element; the South Sea Islanders both classes.

Now with the animals of Africa it must be similar. The native animals whose immunity to tse-tse fly disease surprised Livingstone, are the surviving descendants of those that have had to contest with trypanosomes in the struggle for existence, and have won out. They may still be occasionally infected, but the consequences are not serious. However, the parasites that they have come to resist, when transmitted to animals not so selected, quickly produce the fatal disease.

We have no way of knowing what form the original trypanosome infection of antelopes may

have assumed; at present it seems to be very mild. A somewhat similar condition occurs among rats. In many places in this country young rats are

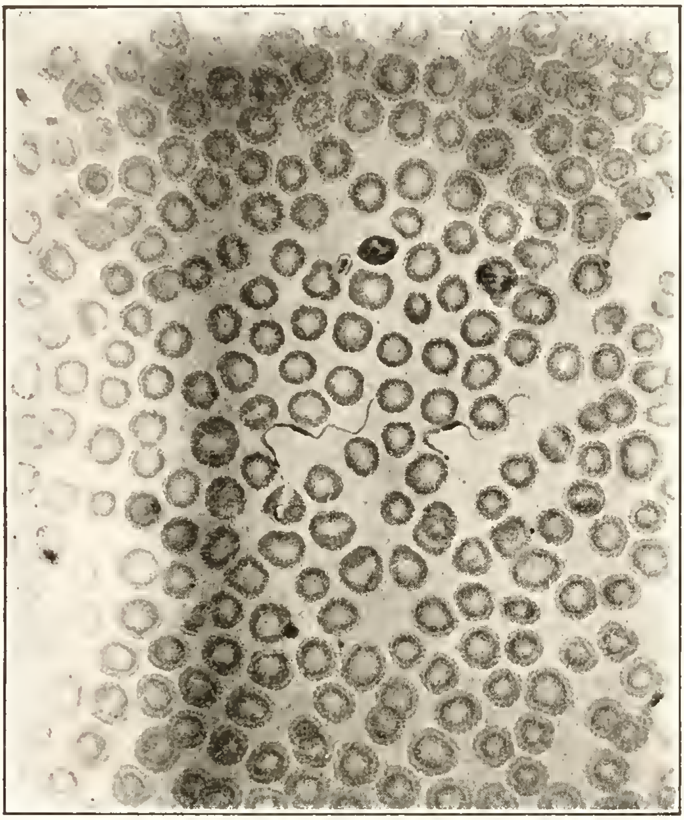


Fig. 63.—Trypanosoma lewisii.

A comparatively harmless blood parasite of rats. The numerous round bodies are red corpuscles; the two dark ones, stained white corpuscles, the parasites are the delicate whip-like bodies of which two near the center show well.

found, upon examination, to harbor trypanosomes —***Trypanosoma lewisii***—which seem not to make them very ill.

Prof. Koch found trypanosomes in the blood of crocodiles, and supposed that, as tse-tse flies seem to prey upon them, they might be the natural reservoirs from which the parasites were obtained. He recommended that all crocodiles be destroyed with poison. But later investigations seem to have exonorated the reptiles from any connection with sleeping sickness and shown that their trypanosome has nothing to do with it.

CONTROL AND PREVENTION OF SLEEPING SICKNESS.

Need it be pointed out that the difficulties in the way of preventing sleeping siekness are very great? Success is only possible where the knowledge and energy of the interested Europeans can be supplemented by co-operation on the part of the natives. Fortunately the latter seems to be easy to secure for they are said to realize the gravity of the situation and want to do all they can to remedy it.

The work has to be conducted on a large scale. In every native village it is necessary to make periodical examinations of every member of the tribe to discover whether he may show the early symptoms of the disease.

These are fortunately easily recognized in the form of swelling of the lymphatic glands, a drop

of the expressed juice from which will be found to contain trypanosomes. Those found infected are removed to special hospital camps where various methods of treatment can be tried, and where they can be kept from the flies while the outcome of the case is awaited. It seems impossible to do more than this with respect to the infected part of the people.

The sanitary officer must next make a careful inspection of the conditions about the native village. If it is found to be near a "fly-belt," it may be necessary to remove and rebuild at some other place. More distant breeding places of the flies must be sought for and destroyed.

Tse-tse flies have peculiar and interesting habits. The females do not lay eggs, but deposit large larvæ, one at a time, upon the sandy bank of a stream or lake. The larva at once bores into the sand to a depth of several inches, and there remains until it is ready to emerge in perfect form. The insects frequent the brush of the banks of the waters on whose shores they breed, and fly up in flocks when animals pass by. They fly only a very short distance, and do not usually separate widely.

These habits make it possible to successfully avoid them. If the brush along the water is cut away, they leave for new shelters. If the infested

localities are known, the villages and roads can be built so as to avoid them.

Avoiding the flies seems to be the only method of preventing infection at present. No successful way of exterminating them has so far been devised. It was once thought that domestic fowls might aid by scratching up and devouring the larvæ, but they bury themselves too deeply.

Wearing clothes would aid in avoiding the infection, by diminishing the exposed parts to which the flies can gain access, but the weather is hot, the people are accustomed to nakedness and clothes are expensive.

EVACUATION OF TERRITORY.

It was at one time suggested that infection might be overcome by a very simple and ingenious expedient. With the co-operation of a native chief, a whole population was moved from a great stretch of country, and kept away for several years. It was supposed that during the time that the country was thus abandoned the infected flies would die of old age, and there being no infected persons from whom new flies could become infected, when the well members of the tribe returned, there would be no more sleeping sickness. But when they returned, the flies were found to be infective, and no good re-

sulted. This we can now easily understand. The insects were, in the absence of the people, infecting themselves from the antelopes.

PROPHETIC REMARK OF DR. LIVINGSTONE.

But through all of the discouragements attending the attempts to control sleeping sickness there is a promise of future hope. It was presaged by Livingstone, and has been echoed by Kinghorn and Yorke. Remember Livingstone's words, "it is probable that with the influence of guns the game will perish, as has happened in the south, and the tse-tse, deprived of food may become extinct simultaneously with the larger animals." "Why not kill all the antelopes?" is the question asked by Kinghorn and Yorke. This is the great hope of the future. With the animals harboring the parasite gone, the disease must become confined to men and insects, and if the insects largely go with the animals, it is quite possible that the disease may disappear.

IS THERE DANGER OF THE DISEASE COMING TO THIS COUNTRY?

We do not believe so. It has been here during slave days and did not spread. We know of no American insect by which it can be spread. There

are no tse-tse flies except in Africa and closely adjacent parts of Asia. Slaves no longer come to bring it. We have no African possessions to take our citizens to the Dark Continent from which they might bring it home with them. Every condition seems to be opposed to its coming or staying. But is there certainly no danger, need the authorities pay no attention? No, indeed! They must be attentive to all infectious diseases, sleeping sickness as well as others, and *not let any come in.* We have no tse-tse flies now, but we may have them. What if somebody should bring them in as the gipsy moths were brought? What if later it should be unexpectedly found, when too late, that we have some other kind of native insect that can serve as the host of the parasite? These are things that we cannot be sure about, but which emphasize the fact that every case of infectious disease, no matter how rare or peculiar, is a matter of concern, and not one should be permitted to come into the country.

CONCLUSIONS.

The realization of the dictum of Pasteur that "It is in the power of man to cause the infectious diseases to disappear from the face of the earth" necessitates determined and prolonged individual and combined "Fighting Foes too Small to See."

That it may be possible is indicated by the brilliant successes that have followed the campaigns against small-pox, typhoid fever, malaria and yellow fever in various countries. Where proper measures have been taken to prevent them, these diseases, once devastating, have become rare.

As the cause and the mode of transmission of an infectious disease become known, the means of preventing it usually soon become easy.

It is more easy to prevent a disease than to cure it; it is more simple to prevent an epidemic than to stop it.

Ignorance of the cause of a disease, or the means of its transmission, may make its prevention impossible. Popular prejudice against measures that are new, selfishness that evades the measures, poverty that may prevent the application of the necessary measures, lack of co-operation on the part of

the people and general indifference on the part of the public, are the factors that interfere with the extinction of the infectious diseases.

They are difficult to overcome. Familiarity with evil breeds contempt for it. Many people in this country are indifferent to the ravages of tuberculosis that destroys about 14 out of 100 of the population, because they have never known anything else.

It seems natural! The people of India are indifferent to the ravages of cholera and plague, because in their experience people have always died of those diseases in large numbers, and it may be the will of the gods that they should continue to do so! And so it goes with the world.

But in the meantime there are for the rest of us two matters of fundamental importance—*Investigation* and *Education.* Without them there can be no progress; with their aid it advances with seven league strides.

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